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Key Words:
Super Compactor
Dynamic Compaction
Low-Level Waste Disposal

Retention:
Permanent

WASTE SUBSIDENCE POTENTIAL VERSUS SUPERCOMPACTION

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September 27, 2001

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Savannah River Site
Aiken, SC 29808

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ACKNOWLEDGEMENTS

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1.0 EXECUTIVE SUMMARY

Solid Waste Division (SWD) disposes of some low-level waste within specially designed concrete vaults. Since the vaults are expensive to design and construct, SWD began utilization of a Waste Sort Facility / Super Compactor Facility to reduce the volume of waste placed in the vaults and thus extend the operational life of the vaults. Recently it was determined that some of the wastes previously disposed in the vaults could be safely disposed in trenches, which are much less expensive to design and construct. The Waste Sort Facility / Super Compactor Facility operational cost is significant relative to the cost of trench design, construction, and operation. Therefore the Solid Waste Division decided to conduct an evaluation to determine if Waste Sort Facility / Super Compactor Facility operation is cost efficient for waste disposed in trenches rather than vaults.

Numerous background paper studies, field tests, and actual field implementations relevant to this evaluation have been discussed and referenced in this report. Waste container data from the Waste Information Tracking System (WITS) on about 6,900 waste containers meeting the waste acceptance criteria for trench disposal have been categorized and presented along with a statistical analysis on the density of this waste. An analysis has been performed on selected waste/subsidence treatment methods to estimate relative subsidence potential, relative closure costs, including the relative waste/subsidence treatment costs, and relative long-term maintenance cost.

Six waste/subsidence treatment methods have been evaluated on an equivalent waste mass basis in order to provide a consistent basis for relative subsidence potential reduction and cost evaluations. The six waste/subsidence treatment methods include:

- An essentially no action case (i.e., direct disposal without waste compaction, followed by emplacement of an interim soil cover, with no dynamic compaction)
- A Waste Sort Facility / Super Compactor Facility processing case
- Two dynamic compaction cases
- Two cases involving both Waste Sort Facility / Super Compactor Facility processing and dynamic compaction

Conclusions of the study include:

- Use of B-25 boxes results in a large inherent subsidence potential which cannot be totally eliminated by any of the methods evaluated. Changing to a disposal container with less structural integrity or waiting until the B-25 boxes have degraded before performing dynamic compaction might reduce the subsidence potential more than the cases evaluated.

- Only two of the treatment methods, tertiary dynamic compaction (i.e. direct disposal without waste compaction, followed by emplacement of an interim soil cover and tertiary dynamic compaction) and the combined use of the Waste Sort Facility / Super Compactor Facility and tertiary dynamic compaction, can reduce the subsidence potential by more than 50%. The combined use of the Waste Sort Facility / Super Compactor Facility and tertiary dynamic compaction results in only an additional seven inches of subsidence potential reduction versus that achieved by tertiary dynamic compaction alone.
- The cost of all cases is dominated by the cost of subsidence repair (7.4 M - 151.7 M), Waste Sort Facility / Super Compactor Facility operation (32.5 M), and B-25 boxes (6.3 M – 10.8 M).
- The large range of costs for subsidence repair reflects the uncertainty in this cost element. It also represents a large number of variables, which can be optimized to produce the greatest potential long-term cost savings.
- Not using the Waste Sort Facility / Super Compactor Facility results in about 72% increase in the size of disposal trench needed to accommodate the same amount of waste. The cost of the increased trench size has been included in the analysis.

Figure 1 shows estimated costs for the cases involving tertiary dynamic compaction. Cost is estimated for each case assuming two different methods of subsidence repair. The near term cost of the tertiary dynamic compaction cases are less than that of the combined use of Waste Sort Facility / Super Compactor Facility and tertiary dynamic compaction. The overall cost favors the combined use of the Waste Sort Facility / Super Compactor Facility and tertiary dynamic compaction only when the traditional method of cap repair is assumed. Due to the large cost of this repair method, it is not likely to be used.

Overall the solid waste division should take an integrated approach which considers the implications of and interactions between disposal operations, waste/subsidence treatments, closure methodology, and long-term maintenance requirements in order to produce an overall strategy which is both technically effective and cost efficient.

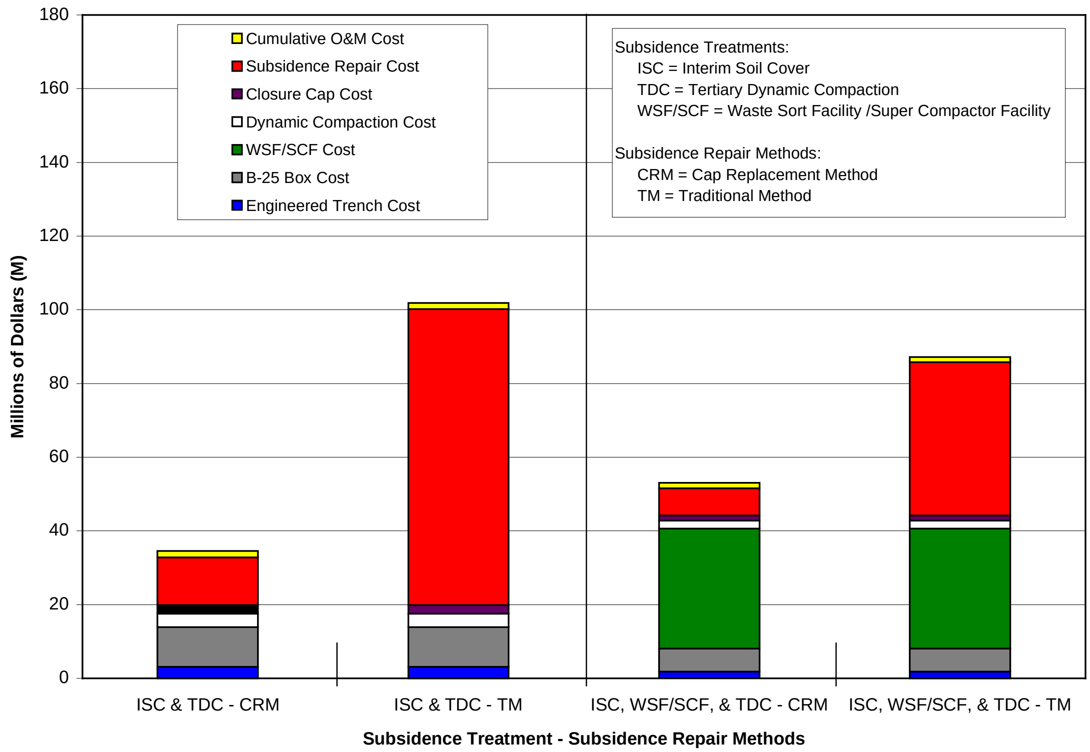

Figure 1. Cost Summary

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2.0 INTRODUCTION

Solid low level radioactive waste (LLW) is disposed at the Savannah River Site (SRS) in the E-Area Low-Level Waste Facility (McDowell-Boyer, et al., 2000). Waste containing lower levels of radioactivity is disposed in earthen trenches designated Engineered Trenches (Wilhite, 2000a; Wilhite, 2000b). Engineered Trenches are excavated to approximately 22 feet below the ground surface, have surface dimensions of approximately 150 feet by 650 feet (i.e. a surface area of approximately 2.2 acres), have an access ramp at one end, and are lined with gravel to facilitate use of a forklift. The excavated soil is stockpiled for later placement over disposed waste.

Each Engineered Trench is designed to contain approximately 12,000 B-25 boxes (Wilhite, 2001d). The B-25s are stacked in rows four high (approximately 17 feet high) with a forklift, beginning at the end of the trench opposite the access ramp. As a sufficient number of B-25 rows are placed, stockpiled soil is bulldozed in a 4-foot lift over some of the completed rows so that the covered rows have at least 4 feet of soil over them. This interim soil cover is only applied to that portion of the completed rows that still allows maintenance of a safe distance from the working face (i.e. where new boxes are placed in the stack) within the trench. The interim soil cover is graded to provide positive drainage off the trench and away from the working face.

Placement of the B-25 boxes continues until the trench is filled with boxes. At that point the minimum 4 feet interim soil cover is placed over the remaining portion of the trench, and the entire area is graded to provide positive drainage off the trench. A final closure cap would subsequently be placed over the Engineered Trench. (Dames & Moore, 1987; Wilhite, 2000a; Wilhite, 2000b; Phifer and Serrato, 2000)

Subsidence of waste in trenches will be potentially disruptive of the closure cap installed after the trench is filled with waste. It has been previously estimated that Engineered Trenches containing B-25 boxes stacked four high have a maximum ultimate subsidence potential of 14.5 feet (Dames & Moore, 1987). Compacting the waste prior to disposal can eliminate some of the voids in waste containers. SRS Solid Waste Division (SWD) currently processes the waste through the Waste Sort Facility / Super Compactor Facility (WSF/SCF) to reduce the subsidence potential prior to disposal of the B-25s in the Engineered Trenches.

At the WSF/SCF, waste is sorted into low-density (such as job control waste) and high-density (such as wood and steel) wastes. Low density waste in 55-gallon drums is compacted in the Super Compactor Facility (SCF) and the resulting waste pucks are placed and stacked in B-25 boxes until the box is filled. Some low-density waste (such as asbestos, PCB, and wetted waste) is not suitable for supercompaction. High-density waste such as wood and steel is placed in B-25 boxes in a manner to minimize void space. Pre-sorted compactable waste is also received directly from the waste generators in 55-gallon drums, ready for supercompaction. (McDowell-Boyer, et al., 2000; Phifer and Serrato, 2000)

The yearly cost of the WSF/SCF facility is in excess of $4,300,000 (Bunker, 2001a). Therefore SWD has requested SRTC to perform a paper study to evaluate the following factors for selected waste/subsidence treatment methods, both with and without the use of the WSF/SCF (Butcher, et al., 2001):

- Relative subsidence potential reduction
- Relative closure costs:
  - Relative Engineered Trench Design and Construction Cost
  - Relative waste/subsidence treatment cost
  - Relative closure cap cost
- Relative long-term maintenance cost
  - Relative closure cap subsidence repair costs
  - Relative cumulative operating and maintenance (O&M) cost

This study uses data on SRS waste containers along with pertinent past studies to provide estimates for the above items for the following selected waste/subsidence treatment methods:

- Placement of an interim soil cover over uncompacted B-25 boxes stacked within an Engineered Trench (ISC). This is considered the no action case.
- Placement of an interim soil cover over B-25 boxes processed through the Waste Sort Facility/Super Compactor Facility (WSF/SCF) and stacked within an Engineered Trench (ISC & WSF/SCF)
- Standard dynamic compaction of uncompacted B-25 boxes stacked within an Engineered Trench that had received an interim soil cover (ISC & SDC)
- Tertiary dynamic compaction of uncompacted B-25 boxes stacked within an Engineered Trench that had received an interim soil cover (ISC & TDC) Standard dynamic compaction of stacked B-25 boxes that have been processed through the WSF/SCF within an Engineered Trench that had received an interim soil cover (ISC, SDC, & WSF/SCF)
- Tertiary dynamic compaction of stacked B-25 boxes that have been processed through the WSF/SCF within an Engineered Trench that had received an interim soil cover (ISC, TDC, & WSF/SCF)

3.0 BACKGROUND STUDIES

Several paper studies, field tests, and actual field implementations have been performed that are relevant to the evaluation of subsidence and subsidence control methods for stacked B-25 boxed waste in Engineered Trenches and the subsequent impact upon closure caps. Pertinent summary information from these studies is provided and forms the basis for the assumptions made in this study.

3.1 B-25 BOX LOADING STUDY

The Savannah River Laboratory (SRL) conducted a loading study of B-25 boxes in 1986. It was implied, but not directly stated in the report, that the testing was performed on a single empty B-25 box without any lateral side support. This study concluded that the lid of the top B-25 in a stack of four boxes would be subjected to a uniform soil load and would behave similar to a simply supported floor slab. It was concluded that the sides of underlying boxes would be subjected to a compressive load and that the lids of underlying boxes would not initially be subjected to any loading. This was concluded due to the nature of the box stacking, where the risers of the box above transfer the load to the sides of the box below rather than to the lid.

The associated testing concluded that the B-25 lid would start to deform and then collapse into the box under loads of approximately 30 psf and 1100 psf, respectively. These loads are equivalent to soil surcharges of approximately 0.3 feet and 10.5 feet, respectively. The testing also concluded that complete collapse of the box would occur under a load of approximately 1700 psf, which is equivalent to a soil surcharge of approximately 16 feet.

Since the testing was performed on a single empty B-25 box without any lateral side support, the test results associated with the lid of the top box are assumed to be fairly representative. However, the test results associated with total collapse of the boxes probably does not represent reality, since the test did not account for the lateral side support provided by adjacent boxes and their interior waste. Since this study did not account for the lateral side support provided by stacks of boxes in an Engineered Trench, the actual load required for complete collapse of boxes in this condition would be much greater than determined from this study. (Yau, 1986)

3.2 STACKED B-25 BOX SUBSIDENCE ESTIMATE

Dames & Moore conducted a paper study of B-25 subsidence in 1987. They produced an estimate of the maximum ultimate subsidence for Engineered Trenches containing uncompacted B-25 boxes stacked four high. Their estimate was based upon the following:

- The Savannah River Plant (SRP) estimated “that the typical box consists of 70 percent void space and 30 percent waste material.”
- The interior height of each box is 3.917 feet.

- It was assumed that "total collapse of the void space and" that an "approximately 75 percent reduction in the thickness of the waste materials" would ultimately occur.
- The void space due to the 4" risers was not considered.
- This resulted in an estimated maximum ultimate subsidence of 14.5 feet as follows:

$$(4\times0.70\times3.917')+(4\times0.30\times3.917'\times0.75) = 14.5'$$

The Dames & Moore analysis divided the 14.5 foot maximum ultimate subsidence of uncompacted B-25 boxes stacked four high into three components:

- **Box Buckling**: It was estimated that 2.5 to 3.5 feet of subsidence would occur from B-25 box buckling due to overburden stress (i.e. soil cover over the boxes). It was estimated that buckling would begin with the breach of the top B-25 lid with as little as 3.3 feet of soil over it. It was also estimated that complete buckling of the bottom box would occur with 13.7 feet of soil over the stack of boxes. It was assumed "that the buckling of these boxes would occur in a random manner over a long period of time throughout the" trench, due to the restraint provided by surrounding boxes.
- **Box Corrosion:** It was estimated that 7.5 to 8.5 feet of subsidence would occur from B-25 box corrosion and subsequent collapse. It was estimated that "it would take about 30 years to perforate the 14 gauge material" of the box, but that "the time-dependent effects of corrosion on the degradation of box strength could not be evaluated at" that time.
- **Waste Degradation and Consolidation:** It was estimated that 3.5 feet of subsidence would occur due to waste degradation and consolidation.

Dames & Moore estimated that the combined subsidence due to B-25 buckling and B-25 corrosion/collapse was a total of 11 feet, and that even if buckling did not produce its estimated full subsidence of 2.5 to 3.5 feet, corrosion/collapse would make up the remainder of the 11-foot total. They finally concluded "that subsidence is expected to be seen as an initial settlement during construction, followed by" a "progressive, somewhat erratic pattern of settlement over a very long period of time." (Dames & Moore, 1987)

3.3 KAOLIN CAP SUBSIDENCE DEMONSTRATION

Dr. Richard C. Warner of the University of Kentucky performed a kaolin clay cap subsidence field demonstration in 1988. This demonstration concluded that a 2-foot thick compacted kaolin layer could span a 3 to 3.5-foot wide cavity without subsidence, but that it would eventually fail and produce subsidence over a 4-foot wide cavity. It was also demonstrated that saturated soil conditions reduce the width of cavity that the kaolin can span. (Warner, 1989)

3.4 STATIC SURCHARGE DEMONSTRATION

The Savannah River Plant (SRP) Waste Management Department (WMD) conducted a field evaluation of static surcharge for the stabilization of a 1.5-acre trench containing stacked B-25 boxes during 1988 and 1989. The static surcharge field test consisted of the placement of subsidence monitors and a 25-foot soil surcharge on top of a trench containing B-25 boxes stacked four high, which had an interim soil cover from four to eight feet thick. Over a year period an average subsidence of 2.7 feet was measured over the north two thirds of the trench, which had had an average 7-foot interim soil cover. However a large percentage of the subsidence was due to consolidation within the 7-foot interim soil cover (C. T. Main, 1989a; C. T. Main, 1989b; Phifer, 1991). It is estimated that the 7-foot interim soil cover and the 25-foot surcharge would have resulted in a normal force of approximately 3,300 psf on the top boxes. If an original dry bulk density for the interim soil cover of 90 pcf and a final dry bulk density of 110 pcf is assumed, the consolidation within the interim soil cover would have been approximately 1.3 feet. (Lambe and Whitman, 1969) This leaves approximately 1.4 feet of subsidence that would be due to B-25 box buckling.

3.5 MIXED WASTE MANAGEMENT FACILITY DYNAMIC COMPACTION

In 1989, the Savannah River Site (SRS) Project Management Department (PMD) performed standard dynamic compaction of 58 acres of the Mixed Waste Management Facility (MWMF) including the same 1.5-acre trench containing stacked B-25 boxes that had previously received a static surcharge. The standard dynamic compaction was conducted on a 10-foot square grid pattern using both primary and secondary drops of an 8-foot diameter weight to provide compaction within the center of each grid square. This resulted in the treatment of approximately 50% of the surface area. Standard dynamic compaction of this 1.5-acre trench resulted in the production of "5 to 6 foot craters with an average of 12 drops and final displacements between drops of less than ½-foot." (Phifer, 1991; Phifer and Serrato, 2000)

3.6 SRS SANITARY LANDFILL MATERIAL ANALYSIS

Under the direction of the SRS Environmental Restoration Division (ERD), SEC Donohue, Inc., performed a material analysis of the waste in the SRS Sanitary Landfill. The material analysis included a large-scale measurement of the waste wet bulk density. The wet bulk density was performed by waste excavation, weighing the waste, and calculating the waste volume based upon a survey of the excavation. The average wet bulk density of the waste based upon five large-scale measurements was determined to be approximately 1.5 g/cm^3, and the measurements ranged from 1.2 to 1.7 g/cm^3. The water content of the waste was not determined during this study, so the dry bulk density of the waste could not be determined. (SEC Donohue, Inc., 1992)

3.7 STACKED B-25 BOX DYNAMIC COMPACTION FIELD EVALUATION

The SRS ERD conducted a field evaluation of the dynamic compaction of stacked B-25 boxed waste in a trench during 1992 and 1993. This field evaluation concluded that in general the top boxes of the stack were more fully compacted than the boxes on the bottom. It was also observed that the boxes on the top layer were fused together by their lateral spread and interlocking, which may have inhibited the further effectiveness of dynamic compaction. Some boxes were actually breached.

Finally it was observed that the potential for box corrosion was increased due to the breakage of the protective coating bond with the metal and subsequent exposure of the bare metal. The actual effectiveness of the dynamic compaction was not well documented during this study, but it was noted that effectiveness could be increased by compacting in a pattern that completely covered the entire surface area and compacting until final displacements between drops were less than 0.2 feet. Such a tertiary compaction pattern and displacement criteria was stated to result in a 30% increase in compaction over the standard compaction criteria used to compact the 1.5-acre trench in 1989. (McMullin and Dendler, 1994; Phifer and Serrato, 2000)

3.8 CLOSURE CAP SUBSIDENCE DEMONSTRATION

The SRS ERD performed a clayey sand and Flexible Membrane Liner (FML) / Geosynthetic Clay Liner (GCL) cap subsidence field demonstration during 1992 and 1993. Table 1 provides a summary of the demonstration results along with a comparison to the kaolin clay cap subsidence field demonstration performed by Dr. Richard C. Warner in 1988 (Warner, 1988). Other observations made during this demonstration include the following (Serrato, 1994):

- Failure began at the center of the cavity for both the clayey sand and FML/GCL caps.
- Significant surface loading (i.e. 7500 psf) on the clayey sand and FML/GCL caps with underlying cavities could cause failure in a very short duration.
- Clayey sand and FML/GCL caps with underlying cavities and no surface loading could span the cavities for significant periods prior to failure (i.e. 3 months).

3.9 CLOSURE CAP ECONOMIC EVALUATION

The SRS ERD performed an economic evaluation of various closure cap configurations in1993. This study evaluated site preparation, construction, and post-closure operating and maintenance costs associated with twelve different closure cap configurations for 10 different sizes of surface impoundments ranging in size from 0.1 to 80 acres. The study concluded that in general the most cost effective barrier consisted of a high density polyethylene (HDPE), flexible membrane liner (FML) over a geosynthetic clay liner (GCL) over a clayey sand foundation layer as shown in Figure 2.

Table 1. Closure Cap Subsidence Demonstration Summary Results

Parameter	Kaolin Cap [1]	Clayey Sand Cap [2]	FML/GCL Cap [3]
Span at Failure (ft), Unsaturated Conditions	4	6	7
Span at Failure (ft), Saturated Conditions	2.5	5	7
Hydraulic Conductivity (cm/s)	1.2E-08	2E-06	1E-10
Underlying Cavity Impact on Hydraulic Conductivity	Increased prior to collapse	Remained constant until collapse	Remained constant with strain until tensile failure occurred (i.e. tearing)
Mode of Failure	Catastrophically	Catastrophically	Incremental subsidence until tensile failure

[1] 2-foot thick kaolin clay layer (>90% passing #200 sieve)
[2] 2-foot thick clayey sand layer [SC material based on the Unified Soil Classification System (USCS)]
[3] A 40-mil thick, high density polyethylene (HDPE), flexible membrane liner (FML) over a geosynthetic clay liner (GCL) containing bentonite over a 2-foot thick clayey sand layer (USCS SC material) (Serrato, 1994)

Table 2 provides the estimated closure cap construction costs for 2 and 5 acre FML/GCL caps based upon the 1993 study. Table 2 costs have been modified from those of the 1993 study to exclude site preparation, waste stabilization, fencing, and monitor well costs. These excluded costs, except for waste stabilization, are assumed to not be applicable due to existing E-Area infrastructure. The waste stabilization cost provided in the 1993 report is specific to surface impoundments and as such are not applicable to this study.

Table 3 provides the estimated yearly O&M costs over a 30-year period for 2- and 5-acre FML/GCL caps based upon the 1993 study. Table 3 costs have been modified from those of the 1993 study to exclude groundwater monitoring and fence maintenance. These excluded costs are assumed to be not applicable due to existing E-Area infrastructure. Additionally, the 1993 study estimated the subsidence repair costs based on an assumed 7-foot diameter sinkhole, and an assumed subsidence frequency over a 30-year period. The repair cost for each 7-foot diameter sinkhole was estimated to be $8000 for FML/GCL closure caps, which is equivalent to a repair cost of approximately $210/ft^2. (Bhutani, et al., 1993)

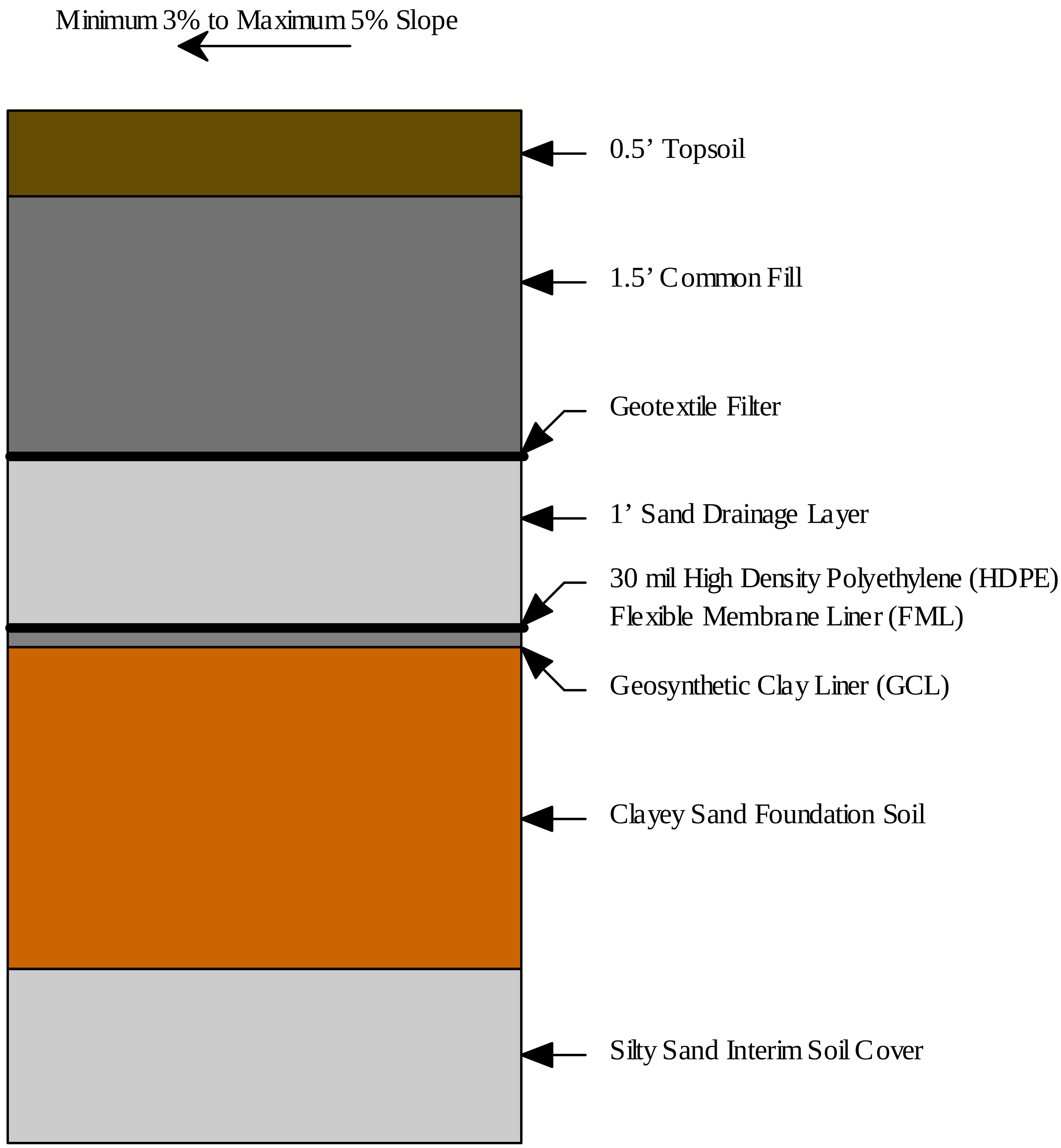

Figure 2. FML/GCL Closure Cap Configuration
(Modified from Bhutani, et al., 1993)

Table 2. FML/GCL Closure Cap Construction Estimates

Closure Cap Construction Activity	1993 2-Acre FML/GCL [1] Cover ($)	1993 5-Acre FML/GCL Cover ($)
Precontouring Site	3,000	4,330
Clayey Sand Foundation Placement	65,040	162,610
GCL Placement	80,800	200,200
FML Placement	39,420	98,580
Sand Drainage Layer Placement	47,920	119,790
Geotextile Filter Placement	3,790	9,460
Common Fill Layer Placement	25,740	64,360
Topsoil Layer Placement	20,130	50,270
Perimeter Drainage Layer Placement	2,760	4,290
Drainage Ditch Construction	4,010	10,030
Seeding, Fertilizing, & Mulching	13,320	33,300
Cover and Subsidence Marker Survey	2,400	3,600
Direct Cost Subtotal	308,330	760,820
Clean up & Demobilization (5% of Direct Cost Subtotal)	15,416	38,041
Location Factor (40% of Direct Cost Subtotal)	123,332	304,328
Total Direct Cost	447,078	1,103,189
Indirect Costs (100% of Direct Costs)	447,078	1,103,189
Total Closure Cap Construction Cost	894,156	2,206,378

Table 3. FML/GCL Closure Cap Yearly O&M Estimates

Closure Cap O&M Activities	1993 2-Acre FML/GCL [1] Cover ($)	1993 5-Acre FML/GCL Cover ($)
Monthly Inspection	4,500	5,400
Annual Subsidence Survey	1,500	1,800
Vegetative Cover Maintenance	1,200	2,500
Total Closure Cap Yearly O&M Cost	7,200	9,700

[1] FML/GCL = high density polyethylene (HDPE), flexible membrane liner (FML) over a geosynthetic clay liner (GCL) over a clayey sand foundation layer

3.10 PRELIMINARY E-AREA TRENCH SUBSIDENCE EVALUATION

The SRS Savannah River Technology Center (SRTC) performed a preliminary E-Area trench subsidence evaluation in 2000. This study estimated the following subcontractor costs associated with the "performance of dynamic compaction based upon the past projects:" (Phifer and Serrato, 2000)

- "Estimated mobilization/demobilization costs: $100,000"
- "Estimated dynamic compaction costs: $200,000 per acre"

3.11 LONG-TERM WASTE STABILIZATION DESIGN TECHNICAL TASK PLAN

SRS SRTC is currently conducting pertinent field testing and finite element modeling under Technical Task Plan SR11SS29, Long-Term Waste Stabilization Design for Long-Term Cover Systems. This is a 3-year study funded by the Department of Energy (DOE) Subsurface Contaminant Focus Area. Work associated with this task is as yet unpublished and preliminary, however what follows are pertinent results obtained to date. On May 3, 2001, a B-25 containing simulated waste (wood) was exhumed after having been buried for approximately 8 years. Initial observations made include the following: (Jones, et al., 2001)

- The uppermost B-25, which was exhumed, was buried approximately 8 feet deep.
- The lid of the uppermost B-25 had collapsed approximately 1.5 feet into the box itself. Without the support provided by the wood contained in the box, the lid may have collapsed deeper into the box.
- The uppermost B-25 was filled with water.
- All exterior surfaces of the uppermost B-25 were damp.
- Paint bubbles covered the exterior surface of the uppermost B-25. Where the paint bubbles had completely debonded from the surface, an iron oxide layer (i.e. rust) had formed. There did not appear to be any corrosion that had perforated the box, and there did not appear to be any significant corrosion on the box interior. All box welds appeared to be intact.
- The bottom and risers of the uppermost B-25 and the lid of the underlying B-25 were intact and no soil was between them, however the lid of the underlying B-25 was damp and soil stained. The underlying B-25 was half full of water.

4.0 WASTE CONTAINER AND OTHER DATA

Data from the SRS Waste Information Tracking System (WITS) on about 6,900 waste containers meeting Waste Acceptance Criteria (WAC) for the Engineered Trench are presented in Table 4 (Wilhite, 2001a). The containers are those located in the Low Activity Waste Vault (LAWV) and temporary storage areas associated with the LAWV (i.e., TRAN1, TRAN2, TRAN5, TRAN6, and TRAN7) and containers located in the Engineered Trench and associated temporary storage areas (i.e., ET-TSA). The information presented, for each type of container, includes the container description, the number of containers, and the average density for that container type. Statistics (i.e., average, standard deviation, minimum, maximum, and median) on the density of containers is also presented.

The data are subdivided into several categories, SRS boxes, non-SRS boxes, and miscellaneous containers. The SRS boxes are further subdivided into the following categories:

- B-25 boxes containing non-compacted waste that pass the Waste Sort Facility (WSF) screening criteria
- B-25 boxes containing non-compacted waste that fail the WSF screening criteria
- B-25 boxes containing supercompacted waste
- B-25 boxes containing compacted waste from the 253-H compactor (purple boxes)
- B-12 boxes

The non-SRS boxes are subdivided into two categories, B-25 boxes and B-12 boxes.

To facilitate projection of waste subsidence and consequent trench cap disruption, only the SRS B-25 boxes containing non-compacted and supercompacted waste will be considered. These containers represent 77% of the total number of containers. The B-25 boxes containing compacted waste from the 253-H compactor are not included because that compactor is no longer operational (Roddy, 2001b).

The inside dimensions of B-25 boxes are 1.83 meters long, 1.17 meters wide, and 1.19 meters high (6 feet long, 3.83 feet wide, and 3.917 feet high). The outside dimensions are 1.85 meters long, 1.19 meters wide, and 1.32 meters high (6.078 feet long, 3.911 feet wide, and 4.323 feet high). The interior volume of a B-25 is 2.55 m^3 (90 ft^3). (Dames & Moore, 1987)

According to the Solid Waste Division (SWD) waste received for potential supercompaction is processed in one of the following two ways:

- Waste received from the generators in B-25 Boxes is processed through the WSF, if it passes the WSF screening criteria, and it is supercompacted in the Super Compactor Facility (SCF), if it passes the SCF compaction criteria.
- Pre-sorted compactable waste is also received at the SCF from the generators in 55-gallon drums. This waste is ready for supercompaction and does not require processing through the WSF.

Table 4. Waste Containers meeting Engineered Trench WAC

Container Description	Number of Boxes	Average Density, g/cc	Standard deviation	Minimum Density	Maximum Density	Median Density
SRS Uncompacted B-25 Boxes:						
Pass WSF Screening Criteria						
B-25 (YELLOW)-LIGHT	818	1.853E-01	1.616E-01	1.779E-02	1.119E+00	1.387E-01
B-25 (6,000# CAP) 672#	25	1.281E-01	5.011E-02	5.623E-02	2.354E-01	1.103E-01
B-25 (YELLOW) 575#	1042	1.965E-01	1.745E-01	3.024E-03	1.183E+00	1.424E-01
B-25 (YELLOW) 625#	1777	1.427E-01	6.265E-02	1.832E-02	3.549E-01	1.291E-01
B-25 OVERPACK - UNRESTRICTED	5	1.926E-01	3.188E-02	1.576E-01	2.411E-01	1.865E-01
B-25(YELLOW) 440 LBS	87	1.734E-01	6.499E-02	6.589E-02	3.456E-01	1.654E-01
Super Compactor B-25 (575#) not compacted	1	1.658E-01	NA			
B-25P (Purple Compactor B-25) not compacted	12	9.391E-02	5.204E-02	2.633E-02	1.713E-01	8.681E-02
Total SRS uncompacted B-25s meeting WSF Screening Criteria	**3767**	**1.673E-01**	1.291E-01	3.024E-03	1.183E+00	1.357E-01
Fail WSF Screening Criteria						
B-25 (YELLOW)-LIGHT	156	1.865E-01	1.475E-01	3.273E-02	6.790E-01	1.248E-01
B-25 (YELLOW) 575#	244	2.284E-01	1.908E-01	1.512E-02	8.405E-01	1.424E-01
B-25 (YELLOW) 625#	288	2.088E-01	1.695E-01	4.145E-02	8.627E-01	1.251E-01
B-25 OVERPACK - UNRESTRICTED	10	1.774E-01	4.375E-02	1.068E-01	2.545E-01	1.775E-01
B-25(YELLOW) 440 LBS	18	3.205E-01	1.744E-01	4.678E-02	5.950E-01	3.779E-01
B-25P (Purple Compactor B-25) not compacted	27	1.962E-01	9.140E-02	3.842E-02	3.132E-01	2.209E-01
Total SRS uncompacted B-25s not meeting WSF Screening Criteria	**743**	**2.124E-01**	1.707E-01	1.512E-02	8.627E-01	1.359E-01
SRS B-25 Boxes containing supercompacted waste	**779**	**7.201E-01**	9.854E-02	4.468E-01	1.341E+00	7.089E-01
SRS B-25P (Purple Compactor B-25) compacted	183	4.371E-01	8.379E-02	2.448E-01	7.208E-01	4.470E-01
SRS B-12	434	4.763E-01	3.288E-01	1.107E-02	1.726E+00	4.134E-01
Non SRS Boxes:						
BETTIS 12,500 CAPACITY B-25	128	1.036E+00	2.399E-01	1.116E-01	1.326E+00	1.085E+00
B-25(BETTIS)	284	4.298E-01	2.163E-01	3.735E-02	1.039E+00	3.949E-01
B-25, KAPL, Stng Tight, Unres.	211	4.050E-01	1.863E-01	1.270E-01	9.360E-01	3.691E-01
B-25 TYPE A (KNOLL-KAPL)	10	2.972E-01	1.678E-01	1.387E-01	5.657E-01	2.259E-01
B-25 PINELLAS	1	5.424E-02	NA	NA	NA	NA
B-12(BETTIS)	17	1.270E+00	3.222E-01	1.506E-01	1.669E+00	1.290E+00
B-12, KAPL, Stng Tight, Unrest	66	8.4541E-01	4.661E-01	2.470E-01	2.694E+00	7.699E-01
B-12 STRONG TIGHT (KNOLL)	5	1.368E+00	1.354E-01	1.227E+00	1.553E+00	1.317E+00
B-12 Type A (Knolls)	1	1.705E-01	NA	NA	NA	NA
Total non-SRS boxes	723					
Miscellaneous Containers						
55-Gal Drum (A,7A)	12	NA	NA	NA	NA	NA
Box for Jumper P-PJ-H-7878	1	NA	NA	NA	NA	NA
Empty 30-Gallon SS Drum	2	NA	NA	NA	NA	NA
NMSS Container for PVV	3	NA	NA	NA	NA	NA
B-1000 AGNS	2	NA	NA	NA	NA	NA
55 Gal Drum (UN1A2)	41	NA	NA	NA	NA	NA
55 Gal Drum (17H Bettis)	9	NA	NA	NA	NA	NA
Bettis DOT 7A Type A	7	NA	NA	NA	NA	NA
KAPL-Windsor (B-82)	49	NA	NA	NA	NA	NA
KAPL-Windsor (B-87)	2	NA	NA	NA	NA	NA
KAPL-Knolls 55-gal drum	9	NA	NA	NA	NA	NA
KAPL-Kesselring 01-2800	25	NA	NA	NA	NA	NA
BAPL-Mixed Fission Products	4	NA	NA	NA	NA	NA
BAPL-Unirradiated Alpha	1	NA	NA	NA	NA	NA
KWD-Low Specific Activity	1	NA	NA	NA	NA	NA
SEG OP45(Retired Do Not Use)	34	NA	NA	NA	NA	NA
SRTC One-Time Shielded Cell	1	NA	NA	NA	NA	NA
SEG OP45	7	NA	NA	NA	NA	NA
KAPL-Windsor Steam Gen Un-Res	5	NA	NA	NA	NA	NA
SRTC Box – 16,000 LB. Capacity	1	NA	NA	NA	NA	NA
SRTC Box – 2000 LB. Capacity	1	NA	NA	NA	NA	NA
55-Gallon Drum, Carolina Metal	4	NA	NA	NA	NA	NA
85-Gallon, Stain. Steel Drum	15	NA	NA	NA	NA	NA
85-Gal Carbon Steel Drum, SW	3	NA	NA	NA	NA	NA
Empty Bung Hole 55-Gallon Drum	1	NA	NA	NA	NA	NA
Total Miscellaneous	240					
Total Number of Containers	6869					

Also, according to SWD, approximately 30% of the B-25 boxes received, on the average, do not pass the WSF screening criteria (Roddy, 2001b) and, of those B-25 boxes sent to the WSF/SCF, about 15% were rejected because the contents were unacceptable for supercompaction (Wilhite, 2001b). Therefore, we have assumed that 60% of the SRS B-25 boxes received by SWD can be supercompacted. These B-25 boxes received, which can be supercompacted, are supercompacted by removing the waste from the B-25 boxes and placing it in 55-gallon drums. The drums are then supercompacted. The supercompacted drums are then loaded into a B-25 box prior to emplacement in the Engineered Trench.

SWD also provided information that the 779 supercompacted SRS B-25 boxes of Table 4 contained 6095 compacted 55-gallon drums of waste that were received directly from the generators at the SCF ready for compaction and, therefore, were not processed through the WSF (Wilhite, 2001e). It is assumed that the split between compacted 55-gallon drums of waste both processed through the WSF and received directly from the generators at SCF is accurately represented by the fraction of each type of drum in the supercompacted SRS B-25 boxes. On the average, 40 supercompacted drums are contained in a B-25 box. The median number of drums is 39, the maximum is 68, the minimum is 24, and the standard deviation is 7.5 drums. Empty 55-gallon drums weigh 36 ± 7.2 pounds (1.633E04 ± 3.266E03 grams). (Roddy, 2001a)

From Table 4, the average density of uncompacted B-25 boxes that pass the WSF screening criteria is 0.1673 grams per cubic centimeter (g/cm^3). The average density of uncompacted B-25 boxes that do not pass the WSF screening criteria is 0.2124 g/cm^3 (see Table 4). The average density of B-25 boxes containing supercompacted waste is 0.7201 g/cm^3 (see Table 4). (Wilhite, 2001a) The average weight of B-25 boxes, including the box itself, that pass the WSF screening criteria, but fail the SCF compaction criteria is 748,430 g (Thomas, 2001).

Based upon the above data the following have been determined and/or calculated. (Appendix A provides the detailed assumptions and calculations. The values presented within the body of the report have been rounded from the values presented in Appendix A):

- If the SCF facility is utilized, both uncompacted and supercompacted B-25s would be disposed in the Engineered Trench. Figure 2 provides the WSF/SCF B-25 process flow diagram based upon the receipt of 100 B-25 boxes by SWD. The detailed assumptions and calculations are provided in Appendix A-1. As shown in Figure 2, every 100 B-25 boxes received by SWD that meet the WAC for the Engineered Trench result in the following for disposal in the Engineered Trench:
    - Approximately 40 uncompacted B-25 boxes with an average waste density of 0.2067 g/cm^3 would be produced.
    - Approximately 21 supercompacted B-25 boxes with an average waste density of 0.7201 g/cm^3 would be produced due to processing through the WSF.
    - Approximately 5 supercompacted B-25 boxes with an average waste density of 0.7201 g/cm^3 would be produced due to pre-sorted compactable waste received from the generators in 55-gallon drums.
    - A total of approximately 66 B-25 boxes with an average waste density of 0.4088 g/cm^3, of which approximately 39% are supercompacted and 61% are uncompacted, would be disposed in the Engineered Trench.

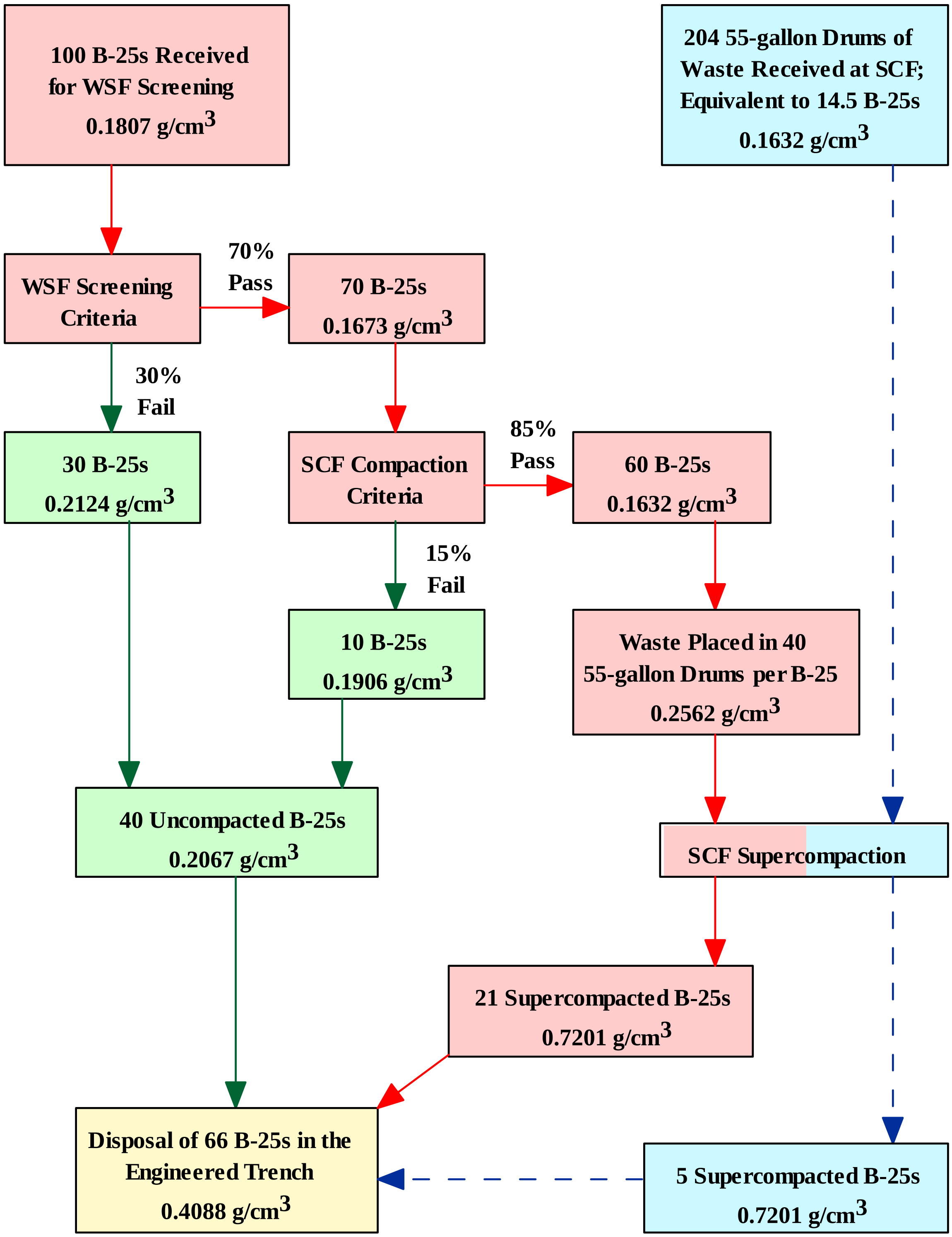

Figure 3. WSF/SCF B-25 Process Flow Diagram

- If the B-25 boxes meeting the Waste Acceptance Criteria (WAC) were not processed through the WSF/SCF prior to disposal in the Engineered Trench, and if the waste received directly from the generators in 55-gallon drums was instead received in B-25 boxes, the average density of the waste within the uncompacted B-25s would be 0.1785 g/cm^3. The detailed assumptions and calculations are provided in Appendix A-2.
- The average B-25 box in an Engineered Trench containing B-25s which have been processed through the WSF/SCF is equivalent to 1.72 average B-25 boxes in an Engineered Trench containing only uncompacted B-25s on a mass equivalent basis. Processing through the WSF/SCF results in disposal of a mixture of supercompacted and uncompacted B-25 boxes. The detailed assumptions and calculations are provided in Appendix A-3.

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5.0 ANALYSIS

An analysis has been performed to estimate the following factors associated with selected waste/subsidence treatment methods:

- Relative subsidence potential reduction
- Relative closure costs
  - Relative Engineered Trench Design and Construction Cost
  - Relative waste/subsidence treatment cost (i.e. B-25 box, WSF/SCF, and dynamic compaction costs)
  - Relative closure cap cost
- Relative long-term subsidence maintenance cost
  - Relative closure cap subsidence repair costs
  - Relative cumulative operating and maintenance (O&M) cost

The items listed are considered to be the primary factors that would influence a relative evaluation of the selected waste/subsidence treatment methods. Other costs would be involved with each selected waste/subsidence treatment method, but an evaluation of the listed costs should provide a fair relative cost evaluation between the methods.

The relative cost of Engineered Trench operation has not been estimated, since the operating costs are basically the costs associated with box handling and such handling costs are assumed to be essentially the same for all cases. Although there are fewer boxes to be disposed within the Engineered Trench for cases involving processing through the WSF/SCF, the WSF/SCF processing involves multiple steps, which result in multiple box handling. Whereas for cases that do not involve processing through the WSF/SCF, more boxes must be disposed within the Engineered Trench, but the boxes require less handling. Therefore, the operating costs for all cases are assumed to be equivalent.

The relative cost of interim soil cover placement has not been estimated due to its assumed minimal cost compared to the other costs under evaluation. Placement of the interim soil cover only involves the bulldozing of already stockpiled soil over the trench using existing labor, which is already performing similar heavy equipment operations within E-Area.

The following are the selected waste/subsidence treatment methods, which have been included in this analysis:

- Placement of an interim soil cover over uncompacted B-25 boxes stacked within an Engineered Trench (ISC). This is considered the no action case.
- Placement of an interim soil cover over B-25 boxes processed through the Waste Sort Facility/Super Compactor Facility (WSF/SCF) and stacked within an Engineered Trench (ISC and WSF/SCF)
- Standard dynamic compaction of uncompacted B-25 boxes stacked within an Engineered Trench that had received an interim soil cover (ISC and SDC)

- Tertiary dynamic compaction of uncompacted B-25 boxes stacked within an Engineered Trench that had received an interim soil cover (ISC and TDC)
- Standard dynamic compaction of stacked B-25 boxes that have been processed through the WSF/SCF within an Engineered Trench that had received an interim soil cover (ISC, WSF/SCF, and SDC)
- Tertiary dynamic compaction of stacked B-25 boxes that have been processed through the WSF/SCF within an Engineered Trench that had received an interim soil cover (ISC, WSF/SCF, and TDC)

This analysis has been performed based upon the following Engineered Trench closure and long-term maintenance strategy for each selected waste/subsidence treatment method evaluated:

- Each of the following disposal, waste/subsidence treatment, and closure activities are assumed to occur immediately after one another with no significant time period between each activity:
  - Waste is processed through the Waste Sort Facility / Super Compactor Facility (WSF/SCF), if applicable to the waste/subsidence treatment method under evaluation.
  - The B-25 boxes containing the waste are stacked four high in the Engineered Trench.
  - A minimum four-foot interim soil cover is placed over the B-25s after the Engineered Trench has been filled.
  - Dynamic compaction is performed, if applicable to the waste/subsidence treatment method under evaluation.
  - A Flexible Membrane Liner / Geosynthetic Clay Liner (FML/GCL) closure cap per Figure 2 is constructed over the Engineered Trench.
- Long-term maintenance begins once the closure cap is completed and continues until the estimated subsidence period has been completed.

All costs presented within this analysis are relative year 2001 costs for comparative purposes only. The costs are not detailed cost estimates. All calculations are provided in Appendix A. The values presented in the body of this report have been rounded off from those presented in Appendix A.

5.1 RELATIVE SUBSIDENCE POTENTIAL

The relative subsidence potential and the relative subsidence potential reduction have been estimated for each of the waste/subsidence treatment methods and the results are provided in Table 5. Appendix A-4 provides the detailed assumptions and calculations associated with the Table 5 estimates. The subsidence potential, resulting from each of the waste/subsidence treatment methods, is based upon the assumption that the waste bulk density will eventually attain a bulk density of 1.5 g/cm^3. A bulk density of 1.5 g/cm^3 is equivalent to a typical bulk density for soil and for typical sanitary landfill waste (Hillel, 1982; Lambe and Whitman, 1969; SEC Donohue, 1992).

Table 5. Relative Subsidence Potential and Relative Subsidence Potential Reduction

Subsidence Treatment Method	Relative Subsidence Potential (ft)	Relative Subsidence Potential Reduction (%)
Base Subsidence Potential [1]	15.1	0.0
ISC	13.6	9.9
ISC and WSF/SCF	11.7	22.6
ISC and SDC	10.4	31.2
ISC and TDC	7.2	52.4
ISC, WSF/SCF, and SDC	9.2	39.5
ISC, WSF/SCF, and TDC	6.6	56.3

[1] Subsidence Potential of a stack of four uncompacted B-25 boxes prior to the placement of the interim soil cover
ISC = Interim Soil Cover; WSF/SCF = Waste Sort Facility / Super Compactor Facility;
SDC = Standard Dynamic Compaction; TDC = Tertiary Dynamic Compaction

5.1.1 Base Subsidence Potential

The base relative subsidence potential, against which all of the waste/subsidence treatment methods have been evaluated, has been estimated at 15.1 feet for a stack of four uncompacted B-25 boxes prior to the placement of the interim soil cover. This estimate is consistent with the previous 14.5-foot estimate made by Dames and Moore (1987) which did not take into account the 1.3-foot subsidence potential due to the B-25 box risers. See Appendix A-4 for the detailed assumptions and calculations. See Table 5 for the summary results, which are based upon the following:

- The vertical dimensions of B-25 boxes stacked four high as shown in Figure 3 prior to any waste/subsidence treatment (Dames and Moore, 1987).
- An interior B-25 box height is 3.9 feet prior to any waste/subsidence treatment as shown in Figure 4 (Dames and Moore, 1987).
- The presence of four risers, each with a vertical void of 0.328 feet, creates a total void of 1.3 feet prior to any waste/subsidence treatment (Dames and Moore, 1987).
- The average density of uncompacted B-25s, where the B-25s are not processed through the WSF/SCF but are placed directly in the Engineered Trench without any supercompaction, is 0.1785 g/cm^3 (see Appendix A-2).

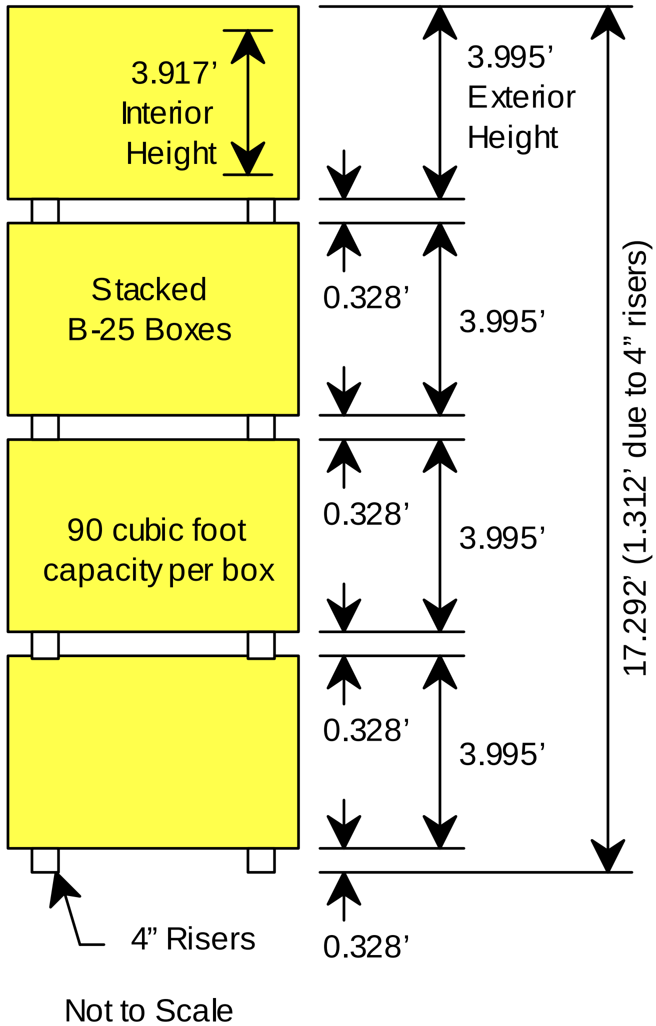

Figure 4. B-25 Boxes, stacked four high

5.1.2 Interim Soil Cover Subsidence Potential

The reduction in subsidence potential resulting from the placement of an interim soil cover over an Engineered Trench containing only uncompacted B-25 boxes has been estimated based upon the Yau (1986), Dames & Moore (1987), and Jones, et al. (2001) studies. Based upon these studies it has been estimated, that when a bulldozer is utilized to place an interim soil cover over stacked uncompacted B-25 boxes, the lid of the top B-25 will collapse approximately 1.5 feet into the box. Therefore, placement of an interim soil cover results in the elimination of 1.5 feet of subsidence potential, which results in a remaining relative subsidence potential of 13.6 feet (15.1 feet minus 1.5 feet; see section 5.1.1 for the base subsidence potential). See Table 5 for the summary results and Appendix A-4 for the detailed assumptions and calculations.

5.1.3 Interim Soil Cover and Waste Sort Facility/Super Compactor Facility Subsidence Potential

The processing of B-25 boxes through the WSF/SCF prior to disposal within an Engineered Trench and the placement of an interim soil cover results in a relative subsidence potential of 11.7 feet. See Appendix A-4 for the detailed assumptions and calculations. See Table 5 for the summary results, which are based upon the following:

- Based upon the Yau, 1986; Dames & Moore, 1987; and Jones, et al., 2001 studies, it is assumed that the lid of uncompacted B-25s will collapse on average 1.5 feet into the box when the interim soil cover is placed with a bulldozer.
- It is assumed that the crushed 55-gallon drums inside a supercompacted B-25 are stacked to within 6 inches of the box lid. Therefore, on average, placement of the interim soil cover can only collapse the lid of the top box 3 inches (0.25 ft) into the box itself due to the curvature produced during lid deformation and collapse.
- Approximately 39% of the B-25s are supercompacted with an average waste density of 0.7201 g/cm^3 (Wilhite, 2001a) and approximately 61% are uncompacted with an average waste density of 0.2067 g/cm^3.
- The average density of B-25s placed in an Engineered Trench after processing through the WSF/SCF is 0.4088 g/cm^3.
- The uncompacted and supercompacted B-25 boxes are randomly placed within the Engineered Trench.

5.1.4 Interim Soil Cover and Dynamic Compaction (Standard and Tertiary) Subsidence Potential

The subsidence potential for both standard and tertiary dynamic compaction of an Engineered trench containing only uncompacted B-25s (i.e. B-25s not processed through the WSF/SCF), which has received an interim soil cover, has been estimated. Standard dynamic compaction is conducted on a 10-foot square grid pattern using both primary and secondary drops of an 8-foot diameter weight to provide compaction within the center of each grid square. This results in standard dynamic compaction treating approximately 50% of the surface area under treatment.

Tertiary dynamic compaction is conducted identical to standard dynamic compaction, but it also involves tertiary drops of the weight at each intersection of the 10-foot grid. Therefore, tertiary dynamic compaction provides essentially 100% treatment of the entire surface area under treatment. Standard dynamic compaction of an Engineered trench containing uncompacted B-25s results in a remaining 10.4-foot subsidence potential, and tertiary dynamic compaction results in a remaining 7.2-foot subsidence potential.

See Appendix A-4 for the detailed assumptions and calculations. See Table 5 for the summary results, which are based upon the following:

- The initial subsidence potential of stacked uncompacted B-25 boxes prior to interim soil cover placement is 15.1 feet as previously determined for the base case (see section 5.1.1).
- Based upon the Yau, 1986; Dames & Moore, 1987; and Jones, et al., 2001 studies, it is assumed that the lid of uncompacted B-25s will collapse on average 1.5 feet into the box when the interim soil cover is placed with a bulldozer.
- The assumed performance of standard dynamic compaction of the Engineered Trench will be based upon the actual results of both the static surcharge and the dynamic compaction of Engineered Low-Level Trench #1 (ELLT-1) that was conducted during closure of the Mixed Waste Management Facility (MWMF). Based upon Phifer, 1991 and Phifer and Serrato, 2000, the dynamic compaction of ELLT-1 produced on average 5.5 foot craters. Based upon C. T. Main 1989a, C. T. Main 1989b, and Phifer, 1991, the static surcharge of ELLT-1 resulted on average 2.7 feet of subsidence over the northern two thirds of the trench. It is assumed that dynamic compaction of ELLT-1 could have achieved the combined results from both the static surcharge and dynamic compaction.
- It is assumed that the ELLT-1 interim soil cover consisted of silty sand (SM) with a bulk density of 90 pcf prior to the static surcharge. After the static surcharge the bulk density of the interim soil cover is assumed to be 110 pcf, and after dynamic compaction the bulk density is assumed to be 120 pcf. This results in the consolidation of the interim soil cover and a decrease in the subsidence potential reduction over the straight addition of the measured ELLT-1 static surcharge and dynamic compaction results.
- It is assumed that tertiary dynamic compaction would produce the same depth craters as standard dynamic compaction, but it would treat 100 percent of the area rather than the 50 percent treated by standard dynamic compaction.

5.1.5 Interim Soil Cover, Dynamic Compaction (Standard and Tertiary), and Waste Sort Facility/Super Compactor Facility Subsidence Potential

The subsidence potential for both standard and tertiary dynamic compaction of an Engineered trench containing supercompacted B-25s (i.e. B-25s processed through the WSF/SCF), which has received an interim soil cover, has been estimated. As stated previously, standard dynamic compaction results in treating approximately 50% of the surface area under treatment, whereas tertiary dynamic compaction provides essentially 100% treatment. Standard dynamic compaction of an Engineered trench containing supercompacted B-25s results in a remaining 9.2-foot subsidence potential, and tertiary dynamic compaction results in a remaining 6.6-foot subsidence potential. See Appendix A-4 for the detailed assumptions and calculations.

See Table 5 for the summary results, which are based upon the following:

- The subsidence potentials for dynamic compaction cases that also include processing through the WSF/SCF are based upon the subsidence potential of the WSF/SCF case from which the remaining impacts due to dynamic compaction are simply subtracted. The initial subsidence potential of an Engineered Trench containing B-25 boxes, which have been processed through the WSF/SCF, and that has received an interim cover is 11.7 feet (see section 5.1.3).
- The maximum subsidence potential reduction that can be produced from the dynamic compaction of a stack of supercompacted B-25 boxes is 3.1 feet. This is based upon the assumption that the crushed 55-gallon drums inside a supercompacted B-25 are stacked to within 6 inches of the box lid, and that dynamic compaction can only eliminate this void space along with the riser void space. Once these two void spaces are eliminated the crushed drums within the supercompacted B-25 form columns which prohibit further dynamic compaction of the box.
- The maximum subsidence potential reduction that can be produced from the dynamic compaction of a stack of uncompacted B-25 boxes is 6.4 feet.
- An Engineered Trench containing boxes processed through the WSF/SCF contains approximately 39% supercompacted boxes and 61% uncompacted boxes.
- The uncompacted and supercompacted B-25 boxes are randomly placed within the Engineered Trench.
- It is assumed that tertiary dynamic compaction would produce the same depth craters as standard dynamic compaction, but it would treat 100 percent of the area rather than the 50 percent treated by standard dynamic compaction.

5.1.6 Subsidence Potential Summary

Table 5 presents the relative subsidence potential for each case evaluated, and it also provides the relative subsidence potential reduction produced by each waste/subsidence treatment method relative to the base subsidence potential. The base subsidence potential is based upon a stack of four uncompacted B-25 boxes prior to placement of the interim soil cover (see section 5.1.1 and Figure 4).

The following are the primary observations and conclusions that can be drawn from the results presented in Table 5:

- Simple placement of an interim soil cover over stacked B-25 boxes is estimated to result in a relative subsidence potential reduction of approximately 10 percent.
- The relative subsidence potential reduction associated with the use of the Waste Sort Facility / Super Compactor Facility (ISC and WSF/SCF) of approximately 23% is substantially less than the approximately 31% produced by Standard Dynamic Compaction (ISC and SDC) or the approximately 52% produced by Tertiary Dynamic Compaction (ISC and TDC).

- ISC and TDC at a relative subsidence potential reduction of approximately 52% appears to be more efficient than the combined use of the WSF/SCF followed by SDC (ISC, WSF/SCF, and SDC), which was estimated at approximately 40% percent.
- The greatest relative subsidence potential reduction was estimated at approximately 56 percent for the combined use of the WSF/SCF followed by TDC (ISC, WSF/SCF, and TDC). However this is only an increase of approximately 4 percent over the use of ISC and TDC.

It should be noted that these relative subsidence potential estimates do not directly take into account the subsidence potential due to degradation of the waste materials themselves other than for B-25 box corrosion. It should also be noted that the dynamic compaction performed to date at SRS has not been optimized to obtain the most compaction reasonably achievable. Such optimization could potentially produce additional subsidence potential reduction over that estimated. Such optimization would need to be based upon both modeling and field studies, and may of course cost more than the standard and tertiary dynamic compaction methodologies outlined above. Dynamic compaction optimization could be realized through both the modification of the dynamic compaction methodology and the timing of dynamic compaction relative to the corrosion and subsequent strength reduction of B-25 boxes.

5.2 RELATIVE ENGINEERED TRENCH DESIGN AND CONSTRUCTION COST

The relative cost of Engineered Trench design and construction has been estimated for each waste/subsidence treatment method. To provide a consistent basis for the relative cost evaluations, all cost evaluations have been performed on an equivalent waste mass basis. See Appendix A-5 for the detailed assumptions and calculations associated with the design and construction costs. See Table 6 for the summary results, which are based upon the following:

- 1.72 B-25 boxes in an Engineered Trench containing only uncompacted B-25s are equivalent on a mass basis to 1 box in an Engineered Trench containing B-25s, which have been processed through the WSF/SCF.
- A direct linear relationship is assumed between the design and construction cost and the number of B-25s to be disposed for each case under consideration.
- An Engineered Trench containing B-25s, which have been processed through the WSF/SCF, will be taken as containing 12,000 B-25 boxes stacked four high (Wilhite, 2001d) and will be taken as having a surface area of 97,500 ft^2 (2.24 acres). The design and construction costs for this Engineered Trench will be taken to be $1.8 M in year 2001 dollars (Bunker, 2001).
- An Engineered Trench containing B-25s, which have not been processed through the WSF/SCF, will be taken as containing 20,640 B-25 boxes stacked four high and will be taken as having a surface area of 167,700 ft^2 (3.85 acres).

As shown in Table 6, all cases involving processing through the WSF/SCF, result in an estimated Engineered Trench design and construction cost of 1.8 M, whereas those cases, which do not involve processing through the WSF/SCF, result in an estimated cost of approximately 3.1 M. Use of the WSF/SCF results in a relative Engineered Trench design and construction cost savings of 1.3 M, due to the smaller size of the Engineered Trench required for cases involving the WSF/SCF.

Table 6. Relative Engineered Trench Design and Construction Cost

Waste/Subsidence Treatment Method	Number of B-25 Boxes Disposed	Relative Engineered Trench Design and Construction Cost ($M)
ISC	20,640	3.1
ISC and WSF/SCF	12,000	1.8
ISC and SDC	20,640	3.1
ISC and TDC	20,640	3.1
ISC, WSF/SCF, and SDC	12,000	1.8
ISC, WSF/SCF, and TDC	12,000	1.8

ISC = Interim Soil Cover; WSF/SCF = Waste Sort Facility / Super Compactor Facility; SDC = Standard Dynamic Compaction; TDC = Tertiary Dynamic Compaction

5.3 RELATIVE WASTE/SUBSIDENCE TREATMENTS COST

The relative cost of waste/subsidence treatment has been estimated for each waste/subsidence treatment method. These costs include the costs of B-25 boxes, the WSF/SCF, and dynamic compaction as appropriate. To provide a consistent basis for the relative cost evaluations, all cost evaluations have been performed on an equivalent waste mass basis. See Appendix A-6 for the detailed assumptions and calculations associated with the waste/subsidence treatment costs. See Table 7 for the summary results, which are based upon the following:

- 1.72 B-25 boxes in an Engineered Trench containing only uncompacted B-25s is equivalent on a mass basis to 1 box in an Engineered Trench containing B-25s, which have been processed through the WSF/SCF.
- An Engineered Trench containing B-25s, which have been processed through the WSF/SCF, will be taken as containing 12,000 B-25 boxes stacked four high Wilhite, 2001d) with a surface area of 2.24 acres (97,500 ft^2).
- An Engineered Trench containing B-25s, which have not been processed through the WSF/SCF, will be taken as containing 20,640 B-25 boxes stacked four high with a surface area of 3.85 acres (167,700 ft^2).

- It has been estimated by SWD that each B-25 box costs approximately $523 (Bunker, 2001b).
- Based upon Table 8, it has been estimated that to supercompact a B-25 box costs approximately $6,876 (Bunker, 2001a; Williams, 2001a; Williams, 2001b).
- The cost of B-25 boxes is not included in the Table 8 WSF/SCF costs, however the cost of 55-gallon drums is included (Bunker, 2001c).
- An Engineered Trench containing boxes processed through the WSF/SCF contains approximate 39% supercompacted boxes and 61% uncompacted boxes.
- Standard dynamic compaction treats approximately 50% of the treatment surface area and tertiary dynamic compaction provides essentially 100% treatment.
- Based upon past SRS experience (1998) the subcontractor costs for performance of standard dynamic compaction has been estimated at $100,000 for mobilization/demobilization plus $200,000 per acre (Phifer and Serrato, 2000).
- Since standard dynamic compaction treats only 50% of the area whereas tertiary dynamic compaction treats 100% of the area and standard dynamic compaction has been estimated to cost $200,000 per acre, tertiary dynamic compaction has been assumed to cost $400,000 per acre. Mobilization/demobilization costs has been assumed to remain at $100,000 for tertiary dynamic compaction. (Phifer and Serrato, 2000).

The following are the primary observations and conclusions associated with the relative waste/subsidence treatment method costs that can be drawn from the results presented in Table 7:

- The relative waste/subsidence treatment cost of the no action case (ISC alone) consists entirely of the cost of B-25 boxes. It has the lowest relative waste/subsidence treatment cost at $10.8 M. Its relative waste/subsidence treatment cost is $1.9 M less than the least expensive dynamic compaction case and $28.0 M less than the least expensive WSF/SCF case.
- All waste/subsidence treatments involving processing through the WSF/SCF have estimated relative waste/subsidence treatment costs at or greater than $38.8 M, with the WSF/SCF accounting for $32.5 M of that and the cost of B-25 boxes making up most, if not all, of the difference.
- All waste/subsidence treatments involving dynamic compaction without processing through the WSF/SCF have estimated relative waste/subsidence treatment costs no greater than $14.4 M. The dynamic compaction portion of that only accounts for at most $3.6 M with the cost of B-25 boxes making up the difference.

- The cost of B-25 boxes is $10.8 M for waste/subsidence treatments that do not involve processing through the WSF/SCF, and $6.3 M for those that do involve processing through the WSF/SCF.
- Use of dynamic compaction without processing through the WSF/SCF results in a waste/subsidence treatment cost savings of at least $24.4 M over cases involving the use of WSF/SCF.
- The cost of processing through the WSF/SCF accounts for at least 79% of the cost for waste/subsidence treatments involving it.
- The cost of either standard or tertiary dynamic compaction is less than 6% of the total waste/subsidence treatment cost for waste/subsidence treatments that involve processing through the WSF/SCF, and less than 25% for waste/subsidence treatments without processing through the WSF/SCF.
- The cost of B-25 boxes alone is greater than 75% of the cost of waste/subsidence treatments involving dynamic compaction alone, and is greater than 15% of the cost of waste/subsidence treatments involving processing through the WSF/SCF.
- The cost of WSF/SCF processing and/or the cost of B-25 boxes are the dominant costs associated with all of the waste/subsidence treatments evaluated.

Table 7. Relative Waste/Subsidence Treatment Cost

Waste/Subsidence Treatment	Waste Mass Equivalent Number of B-25s	Number Supercompacted of B-25s	Engineered Trench Surface Area (acres)
ISC	20,640	0	3.85
ISC and WSF/SCF	12,000	4,728	2.24
ISC and SDC	20,640	0	3.85
ISC and TDC	20,640	0	3.85
ISC, WSF/SCF, and SDC	12,000	4,728	2.24
ISC, WSF/SCF, and TDC	12,000	4,728	2.24

Waste/Subsidence Treatment	B-25 Box Cost ($M)	WSF/SCF Cost ($M)	Dynamic Compaction Cost ($M)	Relative Waste/Subsidence Treatment Cost ($M)
ISC	10.8	0	0	10.8
ISC and WSF/SCF	6.3	32.5	0	38.8
ISC and SDC	10.8	0	1.9	12.7
ISC and TDC	10.8	0	3.6	14.4
ISC, WSF/SCF, and SDC	6.3	32.5	1.2	40.0
ISC, WSF/SCF, and TDC	6.3	32.5	2.2	41.0

Table 8. Cost per Supercompacted B-25 Box

Parameter	FY01	FY02	FY03	FY04	Total
Estimated Number of Supercompacted B-25s	772	643	649	449	2513
WSF ($)	2,610,000	2,610,000	2,610,000	2,610,000	10,440,000
SCF ($)	1,710,000	1,710,000	1,710,000	1,710,000	6,840,000
Total ($)	4,320,000	4,320,000	4,320,000	4,320,000	17,280,000

WSF = Waste Sort Facility; SCF = Super Compactor Facility
(Bunker, 2001a; Williams, 2001a; Williams, 2001b)

5.4 RELATIVE CLOSURE CAP COST

The relative cost of a closure cap has been estimated for each waste/subsidence treatment method. To provide a consistent basis for the relative cost evaluations, all cost evaluations have been performed on an equivalent waste mass basis. See Appendix A-7 for the detailed assumptions and calculations associated with the waste/subsidence treatment costs. See Table 9 for the summary results, which are based upon the following:

- It is assumed that the closure cap over the Engineered Trench will consist of a high density polyethylene (HDPE), flexible membrane liner (FML) over a geosynthetic clay liner (GCL) over a clayey sand foundation layer per Figure 2.
- A 2.61-acre closure cap will be required to cover a 2.24-acre Engineered Trench containing B-25s, which have been processed through the WSF/SCF.
- A 4.28-acre closure cap will be required to cover a 3.85-acre Engineered Trench containing B-25s, which have not been processed through the WSF/SCF.
- It is assumed that the cost of the FML/GCL closure caps can be determined from the estimated closure cap construction costs provided in Table 2 for a 2 and 5 acre cap (Bhutani, et al., 1993).
- A direct linear relationship is assumed between cost and the acreage of the closure cap.

As can seen from Table 9, a 2.24-acre closure cap at a relative cost of $1.5 M is required for all cases involving processing through the WSF/SCF. Whereas, a 4.28-acre closure cap at a relative cost of $2.4 M is required where the WSF/SCF is not utilized. Use of the WSF/SCF results in a relative closure cap cost savings of $0.9 M, due to the smaller size of the Engineered Trench required for cases involving the WSF/SCF.

Table 9. Relative Closure Cap Cost

Waste/Subsidence Treatment	Engineered Trench Surface Area (acres)	Closure Cap Surface Area (acres)	Relative FML/GCL Closure Cap Cost ($M)
ISC	3.85	4.28	2.4
ISC and WSF/SCF	2.24	2.61	1.5
ISC and SDC	3.85	4.28	2.4
ISC and TDC	3.85	4.28	2.4
ISC, WSF/SCF, and SDC	2.24	2.61	1.5
ISC, WSF/SCF, and TDC	2.24	2.61	1.5

ISC = Interim Soil Cover; WSF/SCF = Waste Sort Facility / Super Compactor Facility;
SDC = Standard Dynamic Compaction; TDC = Tertiary Dynamic Compaction

5.5 TOTAL RELATIVE CLOSURE COST SUMMARY

Table 10 provides the total relative closure costs, which consist of the following as stated previously (see Appendix A-11 for the detailed calculations):

- Relative Engineered Trench Design and Construction Cost
- Relative waste/subsidence treatment cost (i.e. B-25 box, WSF/SCF, and dynamic compaction costs)
- Relative closure cap cost

The following are the primary observations and conclusions associated with the total relative closure costs that can be drawn from the results presented in Table 10:

- Use of the WSF/SCF results in a relative Engineered Trench design and construction cost savings of $1.3 M over cases not involving its use.
- The no action case (ISC alone) has the lowest relative closure cost at $16.3 M. Its relative closure cost is $1.9 M less than the least expensive dynamic compaction case and $25.8 M less than the least expensive WSF/SCF case.
- Use of dynamic compaction without processing through the WSF/SCF results in a waste/subsidence treatment cost savings of at least $24.4 M over cases involving the use of WSF/SCF.
- Use of the WSF/SCF results in a relative closure cap cost savings of $0.9 M over cases not involving its use.
- Use of dynamic compaction without processing through the WSF/SCF results in a total relative closure cost savings of at least $22.2 M over cases involving the use of WSF/SCF.

Table 10. Total Relative Closure Costs

Waste/Subsidence Treatment Method	Relative Engineered Trench Design and Construction Cost ($M)	Relative Waste/ Subsidence Treatment Cost ($M)	Relative FML/GCL Closure Cap Cost ($M)	Total Relative Closure Cost ($M)
ISC	3.1	10.8	2.4	16.3
ISC and WSF/SCF	1.8	38.8	1.5	42.1
ISC and SDC	3.1	12.7	2.4	18.2
ISC and TDC	3.1	14.4	2.4	19.9
ISC, WSF/SCF, and SDC	1.8	40.0	1.5	43.3
ISC, WSF/SCF, and TDC	1.8	41.0	1.5	44.2

ISC = Interim Soil Cover; WSF/SCF = Waste Sort Facility / Super Compactor Facility;
SDC = Standard Dynamic Compaction; TDC = Tertiary Dynamic Compaction

To provide an evaluation of the closure cost effectiveness of each waste/subsidence treatment method relative to the subsidence potential reduction it produces, the total relative closure cost per percent relative subsidence potential reduction has been calculated for each method. This ratio essentially provides a way to measure "your bang for your buck" relative to subsidence potential reduction. The calculation summary results are provided in Table 11. (See Appendix A-11 for the detailed calculations.) Overall, from a total relative closure cost and relative subsidence potential reduction perspective, the use of tertiary dynamic compaction alone appears to be the most cost-efficient method evaluated versus closure costs and subsidence potential reduction.

Table 11. Total Relative Closure Cost per Relative Subsidence Potential Reduction

Waste/Subsidence Treatment Method	Total Relative Closure Cost ($M)	Relative Subsidence Potential Reduction (%)	Closure Cost per Subsidence Potential Reduction ($M / %)
ISC	16.3	9.9	1.6
ISC and WSF/SCF	42.1	22.6	1.9
ISC and SDC	18.2	31.2	0.6
ISC and TDC	19.9	52.4	0.4
ISC, WSF/SCF, and SDC	43.3	39.5	1.1
ISC, WSF/SCF, and TDC	44.2	56.3	0.8

ISC = Interim Soil Cover; WSF/SCF = Waste Sort Facility / Super Compactor Facility;
SDC = Standard Dynamic Compaction; TDC = Tertiary Dynamic Compaction

5.6 RELATIVE CLOSURE CAP SUBSIDENCE REPAIR COST

The following two methods of closure cap subsidence repair have been evaluated to provide a range of anticipated relative closure cap subsidence repair costs:

- The traditional method consists of closure cap repair immediately after each subsidence event occurs, during the estimated duration of subsidence.
- The cap replacement method consists of the following two actions during the estimated duration of subsidence:
  - Subsidence holes will be filled in with soil to maintain the grade and promote runoff soon after each subsidence event occurs.
  - The entire cap will be replaced periodically during the duration of subsidence at a frequency based upon the relative subsidence potential associated with each case. The old cap will not be removed, but a new cap will be placed directly on top of the old liner after removing overlying materials.

The closure cap subsidence repair costs are dependent upon the anticipated duration of subsidence. Based upon the following items a period of B-25 box structural collapse (i.e. a subsidence period) has been assumed for both the cases involving and not involving dynamic compaction:

- Dynamic compaction can result in the breakage of the protective coating bond away from the metal resulting in the increased potential for corrosion (McMullin and Dendler, 1994).
- Preliminary results from the exhumation of the B-25 box on May 3, 2001, indicated that very little corrosion of the box occurred over an eight year burial period (Jones, et al., 2001).

Based upon these observations, the period of B-25 box structural collapse (i.e. a subsidence period) has been assumed to be from 200 to 300 years after burial for B-25s that are not dynamically compacted. It has been assumed to be from 100 to 150 years after burial and dynamic compaction for B-25s that are dynamically compacted.

Depending upon the method of closure cap subsidence repair utilized, the costs are also assumed to be dependent upon the relative subsidence potential and either the Engineered Trench surface area or the closure cap surface area. Table 12 provides all of these parameters which are assumed to impact the long-term subsidence of the closure cap and subsequently the closure cap subsidence repair costs.

Table 12. Long-term Subsidence Parameters

Waste/Subsidence Treatment	Subsidence Period (years)	Relative Subsidence Potential (ft)	Engineered Trench Surface Area (ft^2)	Closure Cap Surface Area (acres)
ISC	200 to 300	13.6	167,700	4.28
ISC and WSF/SCF	200 to 300	11.7	97,500	2.61
ISC and SDC	100 to 150	10.4	167,700	4.28
ISC and TDC	100 to 150	7.2	167,700	4.28
ISC, WSF/SCF, and SDC	100 to 150	9.2	97,500	2.61
ISC, WSF/SCF, and TDC	100 to 150	6.6	97,500	2.61

ISC = Interim Soil Cover; WSF/SCF = Waste Sort Facility / Super Compactor Facility;
SDC = Standard Dynamic Compaction; TDC = Tertiary Dynamic Compaction

5.6.1 Relative Closure Cap Subsidence Repair Cost – Traditional Method

The traditional method of closure cap subsidence repair is based on the typical requirements associated with RCRA/CERCLA closure caps, and is therefore considered the current closure cap repair baseline. This method consists of closure cap repair soon after each subsidence event occurs, during the anticipated duration of subsidence. The relative cost of a closure cap subsidence repair utilizing the traditional method has been estimated for each waste/subsidence treatment method. These estimated costs are assumed to represent the upper range of probable closure cap, subsidence repair costs. To provide a consistent basis for the relative cost evaluations, all cost evaluations have been performed on an equivalent waste mass basis. See Appendix A-8 for the detailed assumptions and calculations associated with the traditional, closure cap, subsidence repair costs. See Table 13 for the summary results, which are based upon the following:

- It is assumed that the Table 12 parameters impact the long-term subsidence of the closure cap and subsequently the closure cap subsidence repair costs.
- It is assumed that the closure cap over the Engineered Trench will consist of a high density polyethylene (HDPE), flexible membrane liner (FML) over a geosynthetic clay liner (GCL) over a clayey sand foundation layer.
- It is assumed that subsidence will occur over the entire surface area of the closure cap, which is directly over the Engineered Trench, over the subsidence period (Table 12).
- It is assumed that the number of repair events per area will be proportional to the subsidence potential (Table 12). It is further assumed that every four feet of subsidence will produce a condition requiring repair. Therefore, the number of repair events is assumed to equal the estimated relative subsidence potential divided by four feet. It is assumed that fractions of 4 feet will also require repair due to the extended nature of the subsidence periods.
- A repair cost of $\$266/ft^2$ for a FML/GCL closure cap will be assumed based upon the repair cost for a FML/GCL closure cap estimated by Bhutani, et al., in 1993.

The following are the primary observations and conclusions associated with the traditional, closure cap, subsidence repair costs that can be drawn from the results presented in Table 13:

- The no action case (ISC alone) results in by far the greatest long-term closure cap subsidence repair cost at $149.9 M, due to the large inherent subsidence potential resulting from the use B-25 boxes.
- The long-term closure cap subsidence repair costs associated with the use of only WSF/SCF and only TDC are essentially the same at between $75 M and $80 M. Using only WSF/SCF results in a smaller area that must be repaired but in a greater number of repair events than with the use of only TDC.

- The use of TDC rather than SDC results in lower long-term closure cap, subsidence repair costs due to the greater efficiency of TDC to reduce subsidence potential over SDC.
- The case that utilizes both WSF/SCF and TDC results in the lowest long-term closure cap subsidence repair cost at $41.5 M. This cost is lowest since the use of WSF/SCF results in a smaller Engineered Trench Surface Area, and the combined use of WSF/SCF and TDC results in the smallest subsidence potential and lowest resulting number of repair events.

Table 13. Relative Closure Cap Subsidence Repair Cost – Traditional Method

Waste/Subsidence Treatment	Engineered Trench Surface Area (ft^2)	Number of Repair Events	Relative Closure Cap Subsidence Repair Cost - Traditional Method [1] ($M)
ISC	167,700	3.4	151.7
ISC and WSF/SCF	97,500	2.9	75.2
ISC and SDC	167,700	2.6	116.0
ISC and TDC	167,700	1.8	80.3
ISC, WSF/SCF, and SDC	97,500	2.3	59.7
ISC, WSF/SCF, and TDC	97,500	1.6	41.5

ISC = Interim Soil Cover; WSF/SCF = Waste Sort Facility / Super Compactor Facility; SDC = Standard Dynamic Compaction; TDC = Tertiary Dynamic Compaction
[1] Repair Cost = $266/ ft^2 $\times$ Number of Repair Events $\times$ Surface Area (ft^2)

5.6.2 Relative Closure Cap Subsidence Repair Cost – Cap Replacement Method

The cap replacement method consists of filling subsidence holes with soil to maintain the grade and promote runoff as they occur and of replacing the entire closure cap periodically during the duration of subsidence at a frequency based upon the relative subsidence potential associated with each case. The old cap will not be removed, but a new cap will be placed directly on top of the old liner after removing overlying materials. This method of cap repair is not standard practice and is therefore considered innovative and requiring further development prior to implementation. The relative cost of closure cap subsidence repair utilizing the cap replacement method has been estimated for each waste/subsidence treatment method. To provide a consistent basis for the relative cost evaluations, all cost evaluations have been performed on an equivalent waste mass basis. See Appendix A-9 for the detailed assumptions and calculations associated with the cap replacement, subsidence repair costs. See Table 14 for the summary results, which are based upon the following:

- It is assumed that the Table 12parameters impact the long-term subsidence of the closure cap and subsequently the closure cap subsidence repair costs.

- It is assumed that the closure cap over the Engineered Trench will consist of a high density polyethylene (HDPE), flexible membrane liner (FML) over a geosynthetic clay liner (GCL) over a clayey sand foundation layer.
- It is assumed that subsidence will occur over the entire surface area of the closure cap, which is directly over the Engineered Trench, over the subsidence period, but that the entire cap including the overhang will be replaced.
- For B-25s that are not dynamically compacted, the duration of subsidence has been assumed to last 100 years, and for B-25s that are dynamically compacted, the duration of subsidence has been assumed to last 50 years (see section 5.6 and Table 12).
- It is assumed that the cap replacement frequency varies inversely with relative subsidence potential. The cap replacement frequency for the case with the least subsidence potential (i.e. ISC, WSF/SCF, and TDC) has been assumed to be 10 years. All other cap replacement frequencies have been proportioned based upon this case. Partial caps are estimated at the end of the subsidence duration for consistency with the traditional cap repair method.
- Based upon section 5.4, a closure cap over an Engineered Trench that contains B-25s, which have been processed through the WSF/SCF, costs $1.5 M.
- Based upon section 5.4, a closure cap over an Engineered Trench that contains B-25s, which have not been processed through the WSF/SCF, costs $2.4 M.

The following are the primary observations and conclusions associated with the cap replacement subsidence repair costs that can be drawn from the results presented in Table 14:

- The no action case (ISC alone) results in by far the greatest long-term closure cap subsidence repair cost at $49.8 M due to the large inherent subsidence potential resulting from the use of B-25 boxes.
- The long-term closure cap subsidence repair costs associated with the use of only WSF/SCF is approximately $26.2 M, which is more than twice the cost of $12.9 M associated with the TDC case.
- The use of TDC rather than SDC results in lower long-term closure cap, subsidence repair costs due to the greater efficiency of TDC to reduce subsidence potential over SDC.
- The case that utilizes both WSF/SCF and TDC results in the lowest long-term closure cap subsidence repair cost at $7.4 M. This cost is lowest since the use of WSF/SCF results in a smaller Engineered Trench surface area, and the combined use of WSF/SCF and TDC results in the least subsidence potential and therefore the greatest duration between cap replacements and the fewest number of replacement caps.

Table 14. Relative Closure Cap Subsidence Repair Cost – Cap Replacement Method

Waste/ Subsidence Treatment	Duration of Subsidence (years)	Cap Replacement Frequency (years)	Number of Replacement Caps [1]	Cost per Replacement Cap ($M)	Relative Cap Subsidence Repair Cost - Cap Replacement Method [2] ($M)
ISC	100	4.8	20.8	2.4	49.8
ISC and WSF/SCF	100	5.6	17.8	1.5	26.2
ISC and SDC	50	6.3	7.9	2.4	18.9
ISC and TDC	50	9.2	5.4	2.4	12.9
ISC, WSF/SCF, and SDC	50	7.2	6.9	1.5	10.1
ISC, WSF/SCF, and TDC	50	10	5	1.5	7.4

ISC = Interim Soil Cover; WSF/SCF = Waste Sort Facility / Super Compactor Facility;
SDC = Standard Dynamic Compaction; TDC = Tertiary Dynamic Compaction

1 Number of Replacement Caps = Duration of Subsidence (years) ÷ Cap Replacement Frequency (years)

2 Repair Cost = Number of Replacement Caps × Cost per Replacement Cap

5.6.3 Relative Closure Cap Subsidence Repair Cost Summary

The cap subsidence repair costs from both the traditional method (probable upper range of cost) and the cap replacement method (probable lower range of cost) are presented in Table 15. These costs are assumed to represent the range of probable, closure cap subsidence, repair costs based upon the Engineered Trench closure and long-term maintenance strategy outlined in Section 5.0, which includes the use of B-25 boxes for disposal.

The traditional method of closure cap subsidence repair is based on the typical requirements associated with RCRA/CERCLA closure caps. This method consists of closure cap repair soon after the occurrence of each subsidence event, during the anticipated duration of subsidence. The costs associated with this method are assumed to represent the probable upper range of cap subsidence repair costs, and this method is the current closure cap repair baseline.

The cap replacement method consists of filling subsidence holes with soil to maintain the grade and promote runoff as they occur and of replacing the entire closure cap periodically during the duration of subsidence at a frequency based upon the relative subsidence potential associated with each case. The old cap will not be removed, but a new cap will be placed directly on top of the old liner after removing overlying materials. The cap replacement method is based on an alternate concept to that traditionally utilized for RCRA/CERCLA closure caps and is therefore not considered to be standard practice, but it is considered innovative requiring further development prior to implementation. However it is utilized to represent the probable lower range of cap subsidence repair costs.

As can be seen in Table 15,the closure cap repair costs span a wide range of possible costs (i.e. by a factor of 2.9 to 6.2) depending upon the subsidence repair strategy evaluated. These comparisons between the two repair methods evaluated indicate that the subsidence repair strategy requires further consideration in order to produce the most technically effective and cost efficient strategy for implementation.

Additionally, as can be seen in Table 15, the waste/subsidence treatment method evaluated has a tremendous impact upon the closure cap, subsidence repair costs. For the traditional method there is a factor of 3.6 between the lowest and highest cost waste/subsidence treatment method. For the cap replacement method there is a factor of 6.6 between the lowest and highest cost waste/subsidence treatment method. Again, this indicates that the waste/subsidence treatment strategy requires further consideration and additional waste/subsidence treatments may need to be included in the evaluation in order to produce the most technically effective and cost efficient strategy for implementation.

Table 15. Relative Closure Cap Subsidence Repair Cost Summary

Waste/Subsidence Treatment	Relative Cap Subsidence Repair Cost - Traditional Method ($M)	Relative Cap Subsidence Repair Cost - Cap Replacement Method ($M)	Traditional Method / Cap Replacement Method Cost Ratio
ISC	151.7	49.8	3.0
ISC and WSF/SCF	75.2	26.2	2.9
ISC and SDC	116.0	18.9	6.1
ISC and TDC	80.3	12.9	6.2
ISC, WSF/SCF, and SDC	59.7	10.1	5.9
ISC, WSF/SCF, and TDC	41.5	7.4	5.6

ISC = Interim Soil Cover; WSF/SCF = Waste Sort Facility / Super Compactor Facility; SDC = Standard Dynamic Compaction; TDC = Tertiary Dynamic Compaction

5.7 RELATIVE CUMULATIVE OPERATING AND MAINTENANCE COST

The relative cumulative operating and maintenance (O&M) cost has been estimated for each waste/subsidence treatment method. To provide a consistent basis for the relative cost evaluations, all cost evaluations have been performed on an equivalent waste mass basis. See Appendix A-10 for the detailed assumptions and calculations associated with the cumulative O&M costs. See Table 16 for the summary results, which are based upon the following:

- It is assumed that the yearly O&M costs consist of the Table 3 monthly inspections, an annual subsidence survey, and vegetative cover maintenance (Bhutani, et al., 1993).
- A direct linear relationship is assumed between cost and the acreage of the closure cap.
- Based upon the Table 3 values, the yearly O&M cost for a 2.61-acre Engineered Trench containing B-25s, which have been processed through the WSF/SCF is $9,765 in year 2001 dollars.
- Based upon the Table 3 values, the yearly O&M cost for an 4.28-acre Engineered Trench containing B-25s, which have not been processed through the WSF/SCF is $11,528 in year 2001 dollars.
- It is assumed that the subsidence period for the non-dynamically compacted cases is 300 years, and for dynamically compacted cases 150 years.
- It is assumed that the relative cumulative O&M cost consists of the yearly O&M cost performed over the entire period of subsidence (Table 12).

The following are the primary observations and conclusions associated with the relative cumulative O&M costs that can be drawn from the results presented in Table 16:

- The no action case (ISC alone) results in by far the greatest long-term cumulative O&M cost at $3.4 M due to having both the largest closure cap area and the longest subsidence period.
- The long-term cumulative O&M cost associated with the use of only WSF/SCF is approximately $2.9 M, which is not quite twice the cost of $1.7 M associated with both the dynamic compaction cases.
- The cases that utilize both WSF/SCF and dynamic compaction result in the lowest long-term cumulative O&M cost at $1.5 M. This cost is lowest since the combined use of WSF/SCF and TDC results in both the smallest closure cap area and shortest subsidence period.

Table 16. Relative Cumulative O&M Cost

Waste/Subsidence Treatment	Closure Cap Surface Area (acres)	Yearly O&M Cost ($/year)	Subsidence Period (years)	Relative Cumulative O&M Cost [1] ($M)
ISC	4.28	11,528	300	3.5
ISC and WSF/SCF	2.61	9,765	300	2.9
ISC and SDC	4.28	11,528	150	1.7
ISC and TDC	4.28	11,528	150	1.7
ISC, WSF/SCF, and SDC	2.61	9,765	150	1.5
ISC, WSF/SCF, and TDC	2.61	9,765	150	1.5

ISC = Interim Soil Cover; WSF/SCF = Waste Sort Facility / Super Compactor Facility;
SDC = Standard Dynamic Compaction; TDC = Tertiary Dynamic Compaction
[1] Relative Cumulative O&M Cost = Yearly O&M Cost ($/year) × Subsidence Period (years)

5.8 TOTAL RELATIVE LONG-TERM MAINTENANCE COST

Table 17 provides the estimated total relative long-term maintenance range of costs, which consist of the following as stated previously. (See Appendix A-11 for the detailed calculations.)

- Relative closure cap subsidence repair cost (traditional and cap replacement methods)
- Relative cumulative operating and maintenance (O&M) cost

The following are the primary observations and conclusions associated with the total relative long-term maintenance range of costs that can be drawn from the results presented in Table 17:

- The total relative long-term subsidence maintenance cost ranges from $8.8 M to $155.1 M depending upon the closure cap subsidence repair method and waste/ subsidence treatment method evaluated. The dominant cost associated with the total relative long-term maintenance cost is due to the relative cap, subsidence repair costs, which range from $7.4 M to $151.7 M. The estimated cumulative relative O&M cost only ranges from $1.5 M to $3.5 M.
- The no action case (ISC alone) results in by far the greatest long-term maintenance cost ranging from $53.3 M to $155.1 M due to the large inherent subsidence potential resulting from the use of B-25 boxes, which receive no type of compaction.
- The long-term maintenance cost associated with the use of only WSF/SCF ranges from $29.1 M to $78.1 M.

- The use of TDC rather than SDC results in lower long-term closure cap, subsidence repair costs due to the greater efficiency of TDC to reduce subsidence potential over SDC. Therefore TDC use over SDC use is preferred to reduce the long-term maintenance costs.
- The long-term maintenance cost associated with the use of only TDC ranges from $14.7 M to $82.0 M.
- A comparison of the TDC only and WSF/SCF only cases, indicate that the case with the lowest long-term maintenance cost depends upon which closure cap subsidence repair method is utilized. The TDC only long-term maintenance cost is less than half the cost of WSF/SCF only, if the cap replacement subsidence repair method is utilized. However if the traditional subsidence repair method is utilized, WSF/SCF only is slightly less expensive than TDC only. The traditional method is the current closure cap repair baseline, while the cap replacement method represents and innovative approach requiring further development prior to implementation. Again this indicates that the subsidence repair strategy requires further consideration in order to produce the most technically effective and cost efficient strategy for implementation, since it constitutes the predominate cost of long-term maintenance.
- The case that utilizes both WSF/SCF and TDC results in the lowest long-term maintenance cost, which ranges from $8.8 M to $43.0 M. This cost is lowest since the use of WSF/SCF results in a smaller Engineered Trench surface area, and the combined use of WSF/SCF and TDC results in the smallest subsidence potential.
- B-25 box utilization results in a large estimated subsidence potential regardless of the waste/subsidence treatment utilized and in an assumed 150 to 300 years prior to stabilization, which results in the large long-term maintenance costs.
- All of the waste/subsidence treatments are simply efforts that try to reduce the subsidence impacts created by the use of B-25 boxes. However, none of the waste/subsidence treatments fully eliminates the subsidence impacts of B-25 boxes, as evidenced by the long-term maintenance costs.

Table 17. Total Relative Long-term Maintenance Cost

Waste/Subsidence Treatment Method	Relative Cap Subsidence Repair Cost – Traditional Method ($M)	Relative Cap Subsidence Repair Cost - Cap Replacement Method ($M)	Relative Cumulative O&M Cost ($M)	Total Relative Long-term Maintenance Cost Range ($M)
ISC	151.7	49.3	3.5	53.3 to 155.1
ISC and WSF/SCF	75.2	26.2	2.9	29.1 to 78.1
ISC and SDC	116.0	18.5	1.7	20.7 to 117.7
ISC and TDC	80.3	12.8	1.7	14.7 to 82.0
ISC, WSF/SCF, and SDC	59.7	10.1	1.5	11.6 to 61.1
ISC, WSF/SCF, and TDC	41.5	7.4	1.5	8.8 to 43.0

ISC = Interim Soil Cover; WSF/SCF = Waste Sort Facility / Super Compactor Facility;
SDC = Standard Dynamic Compaction; TDC = Tertiary Dynamic Compaction

To provide an evaluation of each waste/subsidence treatment method's long-term maintenance cost effectiveness relative to the subsidence potential reduction it produces, the range of total relative long-term maintenance cost per percent relative subsidence potential reduction has been calculated for each method. This ratio essentially provides a way to measure "your bang for your buck" relative to subsidence potential reduction. The calculation summary results are provided in Table 18. (See Appendix A-11 for the detailed calculations.)

The following are the primary observations and conclusions that can be drawn from the results presented in Table 18:

- The no action case (ISC alone) results in by far the greatest total relative long-term maintenance cost per relative subsidence potential reduction ranging from 5.3 to 15.5 $M/%. Again this is due to the large inherent subsidence potential resulting from the use of B-25 boxes, which receive no type of compaction.
- The total relative long-term maintenance cost per relative subsidence potential reduction associated with the use of only WSF/SCF ranges from 1.3 to 3.5 $M/%, which is more than twice the range of the TDC case, which ranges from 0.3 to 1.5 $M/%.
- The TDC only and WSF/SCF with dynamic compaction cases have values of the total relative long-term maintenance cost per relative subsidence potential reduction that are within a fairly narrow range of either from 0.2 to 0.3 $M/% (cap replacement method) or 0.8 to 1.6 $M/% (traditional method). The range depends upon which closure cap subsidence repair method is considered. The ISC, WSF/SCF, and TDC case has the lowest value of all.

Table 18. Total Relative Long-term Maintenance Cost per Relative Subsidence Potential Reduction

Waste/Subsidence Treatment Method	Total Relative Long-term Maintenance Cost Range ($M)	Relative Subsidence Potential Reduction (%)	Long-term Maintenance Cost per Subsidence Potential Reduction ($M/%)
ISC	52.7 to 153.3	9.9	5.3 to 15.5
ISC and WSF/SCF	29.1 to 78.1	22.5	1.3 to 3.5
ISC and SDC	20.2 to 116.4	31.9	0.6 to 3.6
ISC and TDC	14.5 to 81.1	52.5	0.3 to 1.5
ISC, WSF/SCF, and SDC	11.6 to 61.1	39.4	0.3 to 1.6
ISC, WSF/SCF, and TDC	8.8 to 43.0	56.3	0.2 to 0.8

ISC = Interim Soil Cover; WSF/SCF = Waste Sort Facility / Super Compactor Facility;
SDC = Standard Dynamic Compaction; TDC = Tertiary Dynamic Compaction

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6.0 SUMMARY AND CONCLUSIONS

Six waste/subsidence treatment methods have been evaluated on an equivalent waste mass basis in order to provide a consistent basis for relative subsidence potential reduction and cost evaluations. The cost evaluations have included both relative closure and long-term maintenance costs. The six waste/subsidence treatment methods include an essentially no action case (i.e. emplacement of an interim soil cover alone), a Waste Sort Facility / Super Compactor Facility (WSF/SCF) processing case, two dynamic compaction cases, and two cases involving both WSF/SCF processing and dynamic compaction.

Table 19 and Figure 5 provide a summary of the subsidence potential and subsidence potential reduction for each waste/subsidence treatment method evaluated. Table 20 and Figures 5 and 6 provide a cost summary for each waste/subsidence treatment method. The Figure 5 cost summary involves traditional subsidence repair (probable upper range of cost), whereas Figure 6 involves cap replacement subsidence repair (probable lower range of cost).

Table 21 and Figures 7 and 8 provide the cost per subsidence reduction summary for each waste/subsidence treatment method. The Figure 7 cost per subsidence reduction summary involves traditional subsidence repair, whereas Figure 8 involves cap replacement subsidence repair. Table 22 and Figure 9 provide the total cost per cubic meter of waste received for Engineered Trench Disposal (i.e. volume prior to any waste/subsidence treatment). Figures 10 and 11 provide a cost timeline for the two most technically effective and cost efficient waste/subsidence treatment methods evaluated. The Figure 10 timeline involves traditional subsidence repair, whereas Figure 11 involves cap replacement subsidence repair.

Appendix A provides the detailed assumptions and calculations associated with the summary information presented within the tables and figures.

Following are the primary conclusions that can be drawn from the Table 19 and Figure 5 data relative to subsidence potential and subsidence potential reduction:

- The disposal of uncompacted B-25 boxes stacked four high, which contain waste at a relatively low-density, results in an estimated base subsidence potential of 15.1 feet out of a total stacked height of 17.3 feet. This is a very significant subsidence potential, resulting directly from the use of B-25 boxes for the disposal of low-density waste.
- Only placing an interim soil cover (ISC) over the B-25 boxes in the Engineered Trench is considered the no action case. ISC alone reduces the subsidence potential to 13.6 feet, which is an approximately 10 percent reduction over the base subsidence potential. This still represents a very significant subsidence potential. Therefore ,on a subsidence potential reduction basis, the no action case (ISC alone) is not preferred.
- Use of the Waste Sort Facility/Super Compactor Facility (WSF/SCF) alone (i.e. ISC and WSF/SCF) reduces the subsidence potential to 11.7 feet, which is an approximately 23 percent reduction over the base subsidence potential. Again this still represents a very significant subsidence potential and the reduction in subsidence potential produced by use of WSF/SCF alone is the lowest produced by any of the active waste/subsidence treatment methods. Therefore, on a subsidence potential reduction basis, the WSF/SCF alone case is not preferred.

- Each case which includes tertiary dynamic compaction (TDC) results in a greater subsidence potential reduction for stacked B-25 boxes in the Engineered Trench than the associated case which includes standard dynamic compaction (SDC). Therefore ,on a subsidence potential reduction basis, the TDC case is preferred over the associated SDC case.
- Only the TDC and WSF/SCF and TDC waste/subsidence treatments reduce the subsidence potential by more than 50 percent. TDC alone (ISC and TDC) reduces the subsidence potential to 7.2 feet, which is an approximately 52 percent reduction over the base subsidence potential. The WSF/SCF and TDC combination reduces the subsidence potential to 6.6 feet, which is an approximately 56 percent reduction over the base subsidence potential. The combined use of WSF/SCF and TDC only results in an additional subsidence potential reduction of 4 percent (seven inches) over that of TDC alone. Therefore, the addition of the WSF/SCF to TDC does not appear to be very effective in providing additional subsidence potential reduction.
- B-25 box utilization results in a large estimated subsidence potential (i.e. from 6.6 to 13.6 feet) regardless of the waste/subsidence treatment utilized and results in an extended period, assumed in this study to be 150 to 300 years, prior to Engineered Trench stabilization.

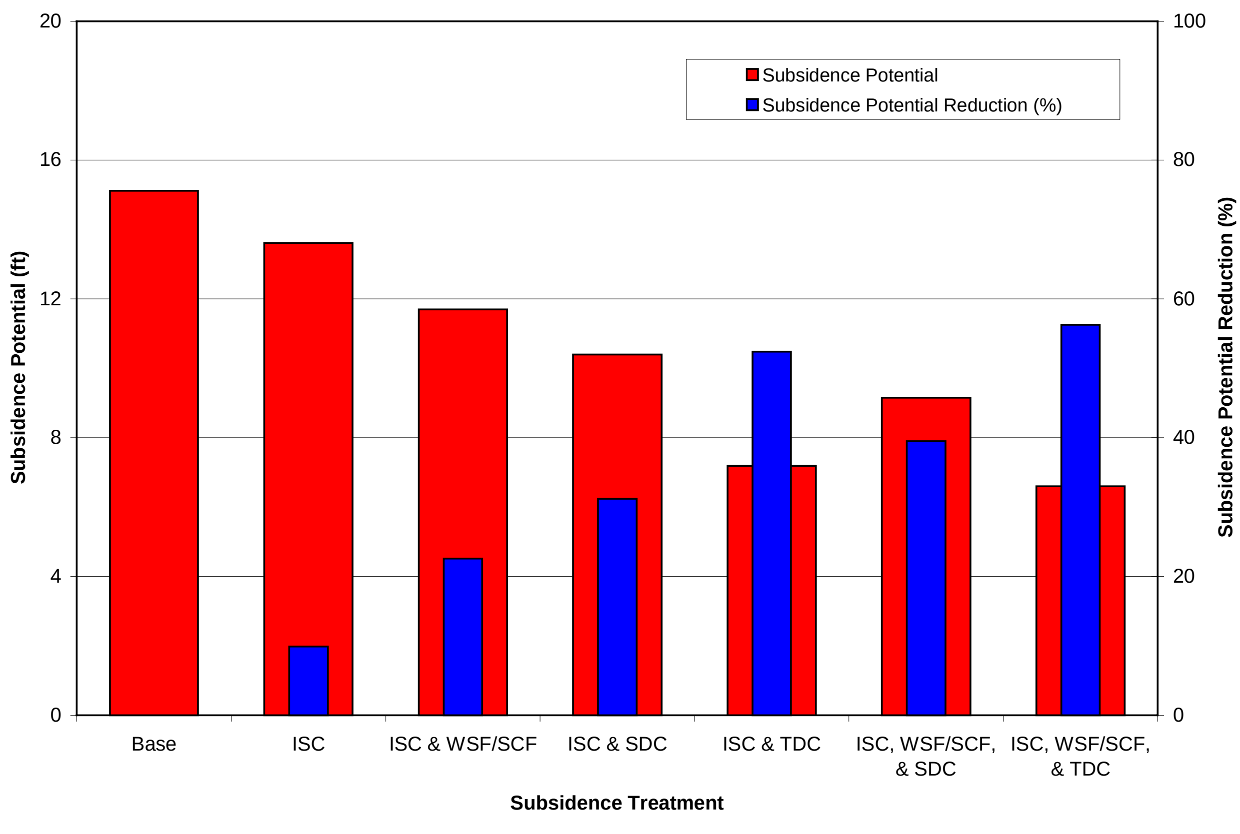

Figure 5. Subsidence Potential and Subsidence Potential Reduction

Table 19. Subsidence Summary

Waste/Subsidence Treatment Method	Engineered Trench Surface Area (acres)	Relative Subsidence Potential (ft)	Relative Subsidence Potential Reduction (%)	Subsidence Period (years)
Base Subsidence Potential	-	15.1	0	-
ISC	3.85	13.6	9.9	200 to 300
ISC and WSF/SCF	2.24	11.7	22.6	200 to 300
ISC and SDC	3.85	10.4	31.2	100 to 150
ISC and TDC	3.85	7.2	52.4	100 to 150
ISC, WSF/SCF, and SDC	2.24	9.2	39.5	100 to 150
ISC, WSF/SCF, and TDC	2.24	6.6	56.3	100 to 150

ISC = Interim Soil Cover; WSF/SCF = Waste Sort Facility / Super Compactor Facility;
SDC = Standard Dynamic Compaction; TDC = Tertiary Dynamic Compaction

The following are the primary conclusions that can be drawn from the Table 20 and Figure 6 and Figure 7 data relative to the cost of the various waste/subsidence treatments:

- The no action case (ISC alone) results in the lowest total closure cost by a slight amount but the greatest subsidence repair cost by a significant margin over all other cases. This results in its having the greatest total cost with the use of traditional subsidence repair and the next to greatest total cost with the use of cap replacement subsidence repair. These high costs are due to the large inherent subsidence potential resulting from the use of B-25 boxes, which receive no type of compaction. Therefore, on a cost basis, the no action case (ISC alone) is not preferred.
- Use of the WSF/SCF alone is the most costly case with the use of cap replacement subsidence repair and the third most costly case with the use of traditional subsidence repair. These high costs are due to the inability of the WSF/SCF as currently operated to significantly reduce the subsidence potential associated with disposal of stacked B-25 boxes in the Engineered Trench. Therefore, on a cost basis, the WSF/SCF alone case (ISC and WSF/SCF) is not preferred.
- Each case, which includes TDC, results in lower subsidence repair cost and subsequently lower total cost than the associated case which includes SDC. This is due to the greater efficiency of TDC, rather than SDC, to reduce the subsidence potential of stacked B-25 boxes in the Engineered Trench. Therefore, on a cost basis, the TDC case is preferred over the associated SDC case.

- Based on a cost basis as outlined above, only two cases of those under evaluation remain which are potentially viable. Those are TDC alone or the combination of WSF/SCF and TDC. While TDC alone has a significantly lower total relative closure cost than WSF/SCF and TDC, the WSF/SCF and TDC case has a lower subsidence repair cost. The WSF/SCF and TDC case has the lower subsidence repair cost, since it results in a slightly greater reduction in subsidence potential and it uses less Engineered Trench space. The case, however, which has the lower total cost, depends upon the subsidence repair method. If the traditional subsidence repair method is utilized, the WSF/SCF and TDC case costs less, however if the cap replacement method is utilized, the TDC alone case costs less.
- The costs of the Engineered Trench, the dynamic compaction, where implemented, the closure cap, and the cumulative O&M are all within the fairly narrow range of $1.2 M to $3.6 M, and contribute little to the total relative costs.
- The primary costs are associated with the B-25 boxes, the WSF/SCF, and subsidence repair. The B-25 box costs range from $6.3 M to $10.8 M depending upon the waste/subsidence treatment method. The WSF/SCF costs $32.5 M, where implemented. The subsidence repair costs range from $7.4 M to $151.7 M depending upon both the waste/subsidence treatment method and the subsidence repair method. The B-25 box costs are always lowest relative to the other two. The WSF/SCF costs, where implemented, are greater than the subsidence repair costs when the cap replacement subsidence repair method is utilized. The subsidence repair costs are greater than the WSF/SCF costs, where implemented, when the traditional subsidence repair method is utilized. The B-25 boxes, the WSF/SCF, and subsidence repair cost elements are the ones with the greatest costs and therefore have the greatest potential to significantly reduce the total costs.
- B-25 box utilization for disposal of relatively low-density waste, which results in large subsidence potentials regardless of the waste/subsidence treatment method, is directly responsible for high B-25 box, WSF/SCF, and subsidence repair costs. All the waste/subsidence treatment methods evaluated are simply efforts that try to reduce the subsidence impacts created by the use of B-25 boxes. However, none of the waste/subsidence treatments fully eliminates the subsidence impacts of B-25 boxes as evidenced by the subsidence repair costs.

Table 20. Cost Summary

Subsidence Treatment Method	Engineered Trench Cost ($M)	B-25 Box Cost ($M)	WSF/SCF Cost ($M)	Dynamic Compaction Cost ($M)	Closure Cap Cost ($M)	Total Relative Closure Cost ($M)
ISC	3.1	10.8	0.0	0.0	2.4	16.3
ISC and WSF/SCF	1.8	6.3	32.5	0.0	1.5	42.1
ISC and SDC	3.1	10.8	0.0	1.9	2.4	18.2
ISC and TDC	3.1	10.8	0.0	3.6	2.4	19.9
ISC, WSF/SCF, and SDC	1.8	6.3	32.5	1.2	1.5	43.3
ISC, WSF/SCF, and TDC	1.8	6.3	32.5	2.2	1.5	44.2

Subsidence Treatment Method	Traditional Subsidence Repair Cost ($M)	Cap Replacement Subsidence Repair Cost ($M)	Cumulative O&M Cost ($M)	Total Relative Long-term Maintenance Cost Range ($M)	Total Relative Cost Range ($M)
ISC	151.7	49.8	3.4	53.3 to 155.1	69.6 to 171.4
ISC and WSF/SCF	75.2	26.2	2.9	29.1 to 78.1	71.2 to 120.2
ISC and SDC	116.0	18.9	1.7	20.7 to 117.7	38.8 to 135.9
ISC and TDC	80.3	12.9	1.7	14.7 to 82.0	34.5 to 101.9
ISC, WSF/SCF, and SDC	59.7	10.1	1.5	11.6 to 61.1	54.9 to 104.4
ISC, WSF/SCF, and TDC	41.5	7.4	1.5	8.8 to 43.0	53.1 to 87.2

ISC = Interim Soil Cover; WSF/SCF = Waste Sort Facility / Super Compactor Facility;
SDC = Standard Dynamic Compaction; TDC = Tertiary Dynamic Compaction;
$M = Millions of Dollars

Note: The higher cost in each range is associated with the traditional method of subsidence repair and the lower is associated with the cap replacement method.

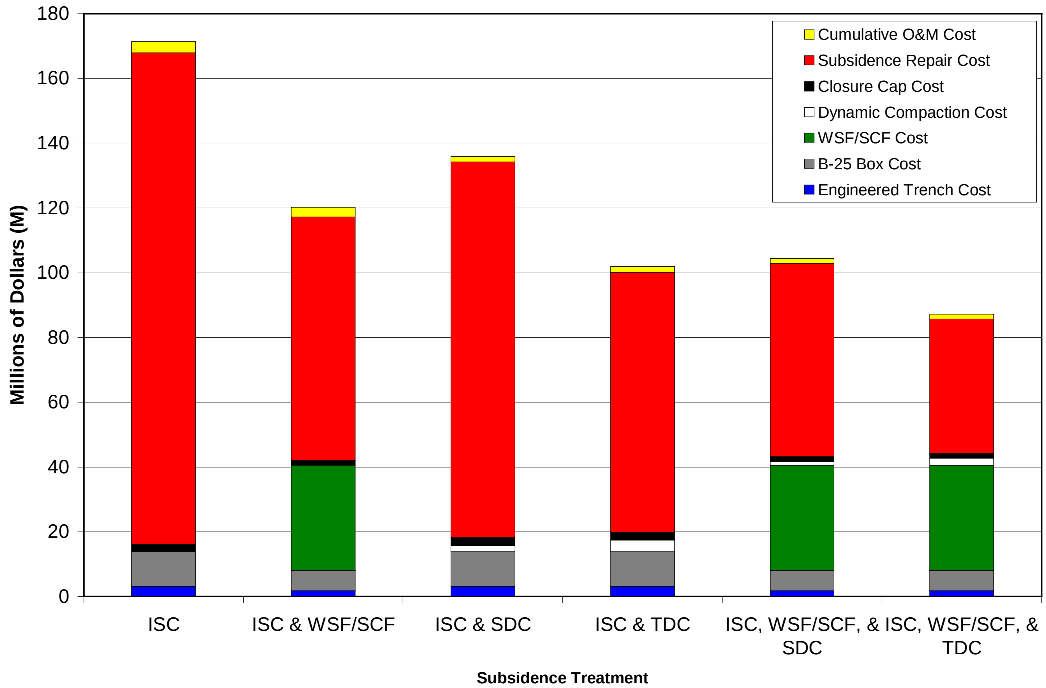

Figure 6. Cost Summary with Traditional Subsidence Repair *

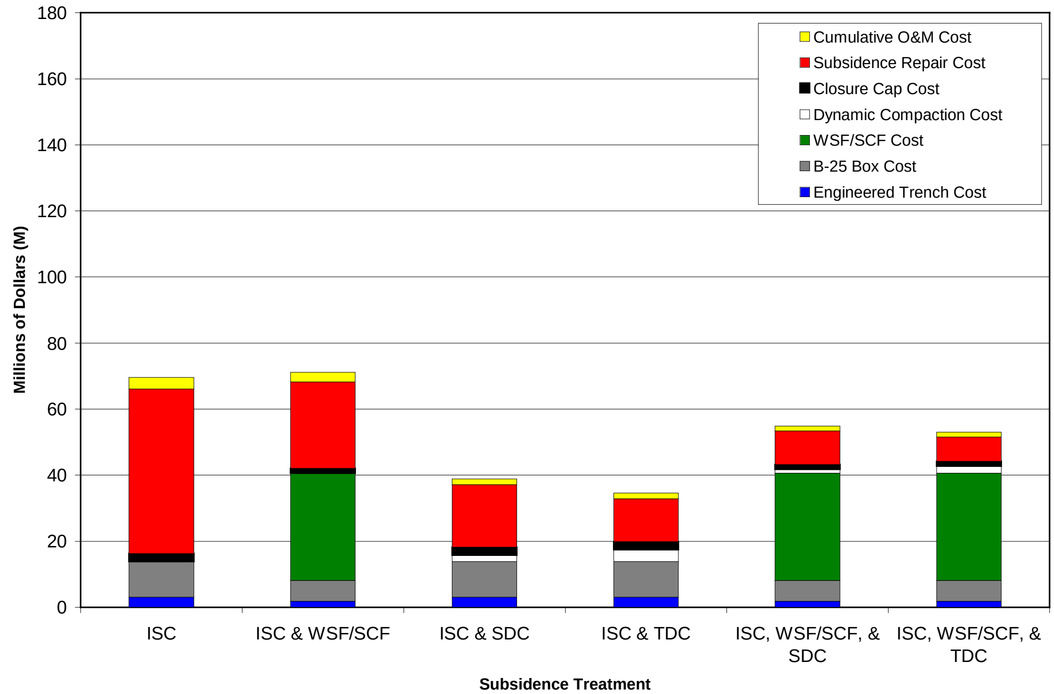

Figure 7. Cost Summary with Cap Replacement Subsidence Repair *

***** Relative position of cost elements on bars is the same as their order in the legend.

The following are the primary conclusions that can be drawn from the Table 21 and Figure 8 and Figure 9 data relative to the cost per subsidence reduction of the various waste/subsidence treatments. This ratio essentially provides a way to measure “your bang for your buck” relative to subsidence potential reduction.

- The no action case (ISC alone) and the WSF/SCF alone case result in the highest total cost per subsidence reduction of any of the other cases. Therefore, on a cost per subsidence reduction basis, the no action case (ISC alone) and the WSF/SCF alone case are not preferred.
- Each case, including TDC, results in a lower cost per subsidence reduction for stacked B-25 boxes in the Engineered Trench than the associated case, which includes SDC. Therefore, on a cost per subsidence reduction basis, the TDC case is preferred over the associated SDC case.
- On a cost per subsidence reduction basis the case with the least cost per subsidence reduction is either TDC alone or the combination of WSF/SCF and TDC. While TDC alone has a lower closure cost per subsidence reduction than WSF/SCF and TDC, the WSF/SCF and TDC case has a lower long-term maintenance cost per subsidence reduction. The case, however, which has the lowest total cost per subsidence reduction, depends upon the subsidence repair method. If the traditional subsidence repair method is utilized, the WSF/SCF and TDC case is lowest, however, if the cap replacement method is utilized, the TDC alone case is lowest.

Table 21. Cost per Subsidence Reduction Summary

Waste/Subsidence Treatment Method	Closure Cost per Subsidence Reduction ($M/%)	Long-term Maintenance Cost per Subsidence Reduction ($M/%)	Total Cost per Subsidence Reduction ($M/%)
The following values are associated with the traditional method of subsidence repair:			
ISC	1.6	15.7	17.3
ISC and WSF/SCF	1.9	3.5	5.3
ISC and SDC	0.6	3.8	4.4
ISC and TDC	0.4	1.6	1.9
ISC, WSF/SCF, and SDC	1.1	1.5	2.6
ISC, WSF/SCF, and TDC	0.8	0.8	1.5
The following values are associated with the cap replacement method of subsidence repair:			
ISC	1.6	5.4	7.0
ISC and WSF/SCF	1.9	1.3	3.1
ISC and SDC	0.6	0.7	1.2
ISC and TDC	0.4	0.3	0.7
ISC, WSF/SCF, and SDC	1.1	0.3	1.4
ISC, WSF/SCF, and TDC	0.8	0.2	0.9

ISC = Interim Soil Cover; WSF/SCF = Waste Sort Facility / Super Compactor Facility;
SDC = Standard Dynamic Compaction; TDC = Tertiary Dynamic Compaction

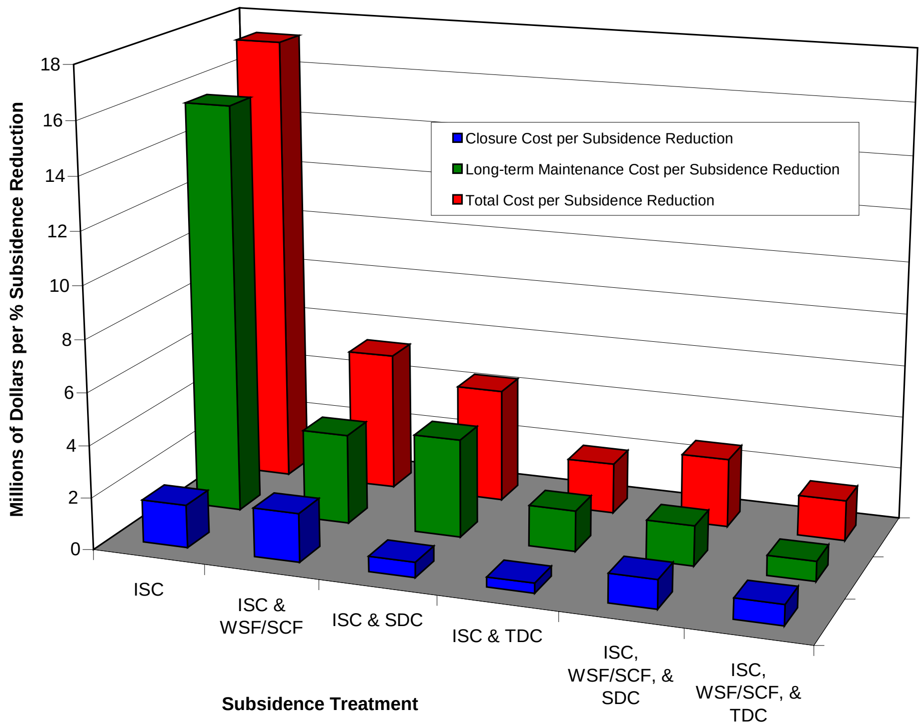

Figure 8. Cost per Subsidence Reduction with Traditional Subsidence Repair

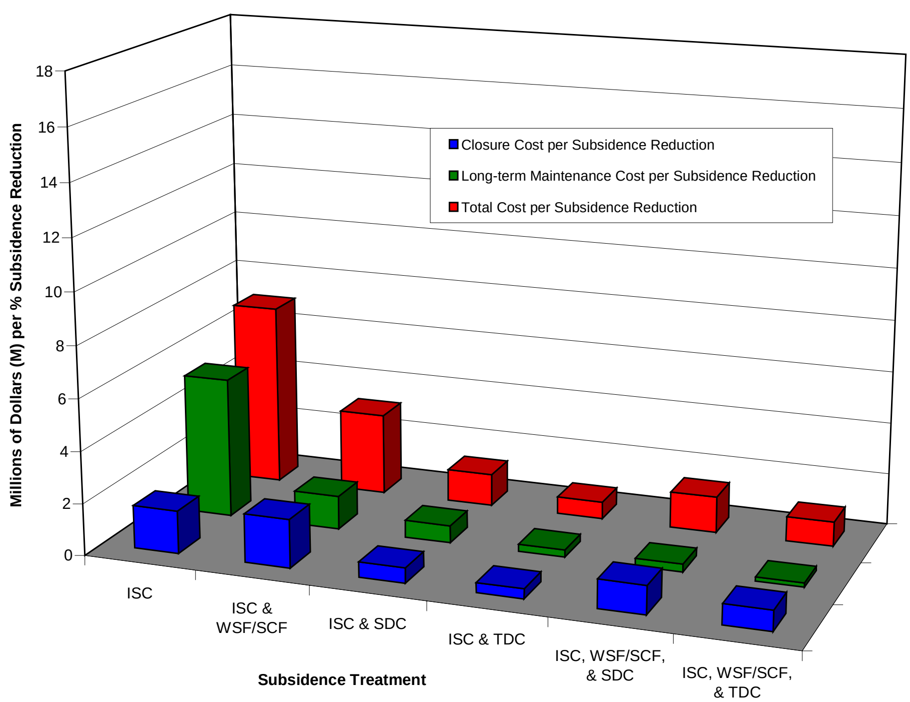

Figure 9. Cost per Subsidence Reduction with Cap Replacement Subsidence Repair

The following are the primary conclusions that can be drawn from the Table 22 and Figure 10 data relative to the total cost per volume of waste received for disposal for the various waste/subsidence treatments:

- The no action case (ISC alone) results in either the highest (with traditional subsidence repair) or next to highest (with cap replacement subsidence repair) total cost per volume of waste received for disposal of any of the other cases. Therefore, on a cost per volume of waste received for disposal basis, the no action case (ISC alone) is not preferred.
- Use of the WSF/SCF alone results in either the highest (with cap replacement subsidence repair) or the third highest (with cap replacement subsidence repair) total cost per volume of waste received for disposal of any of the other cases. These high costs are due to the inability of the WSF/SCF as currently operated to significantly reduce the subsidence potential associated with disposal of stacked B-25 boxes in the Engineered Trench. Therefore, on a cost per volume of waste received for disposal basis, the WSF/SCF alone case (ISC & WSF/SCF) is not preferred.
- Each case including TDC results in a lower cost per volume of waste received for disposal than the associated case, which includes SDC. Therefore, on a cost per volume of waste received for disposal basis, the TDC case is preferred over the associated SDC case.
- On a cost per volume of waste received for disposal basis the case with the least cost per volume of waste received for disposal is either TDC alone or the combination of WSF/SCF and TDC. The case, which has the lowest total cost per volume of waste received for disposal, depends upon the subsidence repair method. If the traditional subsidence repair method is utilized, the WSF/SCF and TDC case is lowest, however if the cap replacement method is utilized, the TDC alone case is lowest.

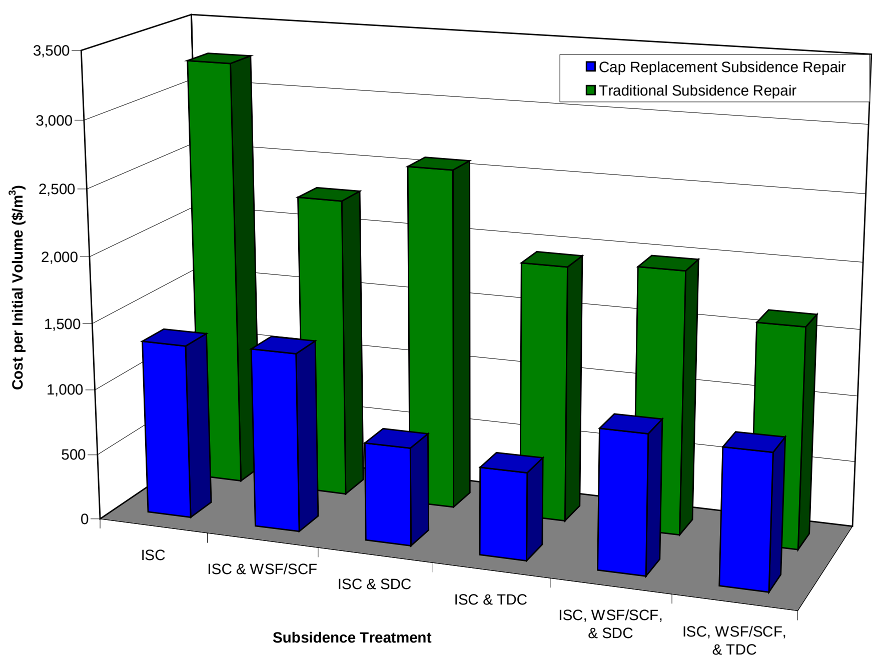

Figure 10. Cost per Volume of Waste Received for Disposal

Table 22. Cost Per Volume of Waste Received for Disposal

Waste/Subsidence Treatment Method	Total Cost ($)	Initial Volume (m^3)	Total Cost per Volume of Waste Received ($/$m^3$)
The following values are associated with the traditional method of subsidence repair:			
ISC	171,413,082	52,632	3,257
ISC and WSF/SCF	120,197,450	52,632	2,284
ISC and SDC	135,898,620	52,632	2,582
ISC and TDC	101,894,818	52,632	1,936
ISC, WSF/SCF, and SDC	104,369,299	52,632	1,983
ISC, WSF/SCF, and TDC	87,193,858	52,632	1,657
The following values are associated with the cap replacement method of subsidence repair:			
ISC	69,583,708	52,632	1,322
ISC and WSF/SCF	71,164,801	52,632	1,352
ISC and SDC	38,846,348	52,632	738
ISC and TDC	34,538,901	52,632	656
ISC, WSF/SCF, and SDC	54,866,781	52,632	1,042
ISC, WSF/SCF, and TDC	53,051,468	52,632	1,008

In summary, of the waste/subsidence treatment methods evaluated, the following cases are not preferred for implementation on the basis of subsidence potential reduction, cost, and cost per subsidence reduction:

- No action case (ISC alone)
- Waste Sort Facility/Super Compactor Facility only case (ISC and WSF/SCF)
- All cases utilizing standard dynamic compaction (i.e. ISC and SDC and ISC, WSF/SCF, and SDC)

Of the remaining two cases evaluated, the following conclusions were drawn on the basis of subsidence potential reduction, cost, cost per subsidence reduction, and cost per volume of waste received for disposal. (See Table 19 through Table 22 and Figure 5 through Figure 10.)

- The combined use of WSF/SCF and TDC only results in an additional subsidence potential reduction of 4 percent (seven inches) over that of TDC alone. Therefore, the addition of the WSF/SCF to TDC does not appear to be very effective in providing additional subsidence potential reduction. However, the addition of the WSF/SCF to TDC does result in the utilization of an Engineered Trench with less surface area by a factor of 1.72.
- The TDC alone case has a lower total relative closure cost and a lower relative closure cost per subsidence reduction than the WSF/SCF and TDC case.
- The WSF/SCF and TDC case has a lower long-term maintenance cost and a lower long-term maintenance cost per subsidence reduction than the TDC alone case. The WSF/SCF and TDC case has the lowest subsidence repair cost, since it results in a slightly greater reduction in subsidence potential and utilizes an Engineered Trench with less surface area by a factor of 1.72.
- The case with the lowest total cost, lowest total cost per subsidence reduction, and lowest cost per volume of waste received for disposal depends upon which subsidence repair method is utilized. If the traditional subsidence repair method is utilized, the WSF/SCF and TDC case is lowest, however if the cap replacement method is utilized, the TDC alone case is lowest.

In order to provide additional perspective relative to the costs of TDC alone and WSF/SCF and TDC, Figure 11 and Figure 11 timelines have been provided. The following are the primary conclusions that can be drawn from Figure 11 and Figure 12:

- For both the traditional (Figure 11) and the cap replacement (Figure 12) subsidence repair methods, the TDC alone case has the lowest up front costs and the highest long-term costs versus the WSF/SCF and TDC case.
- The traditional subsidence repair method results in a large continuous yearly repair cost over a fifty year period for both the TDC alone ($1.6 M / year) and the WSF/SCF and TDC ($0.8 M / year) cases.
- The cap replacement subsidence repair method results in a large repair cost approximately every ten years over a fifty year period for both the TDC alone ($2.6 M / year) and the WSF/SCF & TDC ($1.5 M / year) cases.

The following are additional summary and conclusions resulting from this evaluation:

- The most uncertainty in costs is associated with the long-term subsidence repair costs, which also potentially represent the greatest cost element. The cap replacement subsidence repair method represents the probable lower range of cap subsidence repair costs, whereas the traditional method represents the probable upper range of such costs. The traditional method is the current cap subsidence repair baseline, whereas the cap replacement method is considered innovative and requiring further development prior to implementation. These long-term subsidence repair costs are greatly impacted by the use of B-25 boxes, the waste/subsidence method utilized, and the subsidence repair strategy implemented.
- The B-25 boxes, the WSF/SCF, and subsidence repair cost elements are the ones with the greatest costs and therefore optimization of these elements has the greatest potential to significantly reduce the total costs.
- B-25 box utilization for disposal of relatively low-density waste, which results in large subsidence potentials regardless of the waste/subsidence treatment method evaluated, is directly responsible for high B-25 box, WSF/SCF, and subsidence repair costs. All the waste/subsidence treatment methods evaluated are simply efforts that try to reduce the subsidence impacts created by the use of B-25 boxes. However, none of the waste/subsidence treatments fully eliminates the subsidence impacts of B-25 boxes as evidenced by the subsidence repair costs.
- Significant uncertainty is associated with the timing of B-25 box corrosion and collapse (i.e. time until Engineered Trench stabilization). Within this study this was assumed to occur over a 150-year period for boxes that had been dynamically compacted and over a 300-year period for boxes that had not.

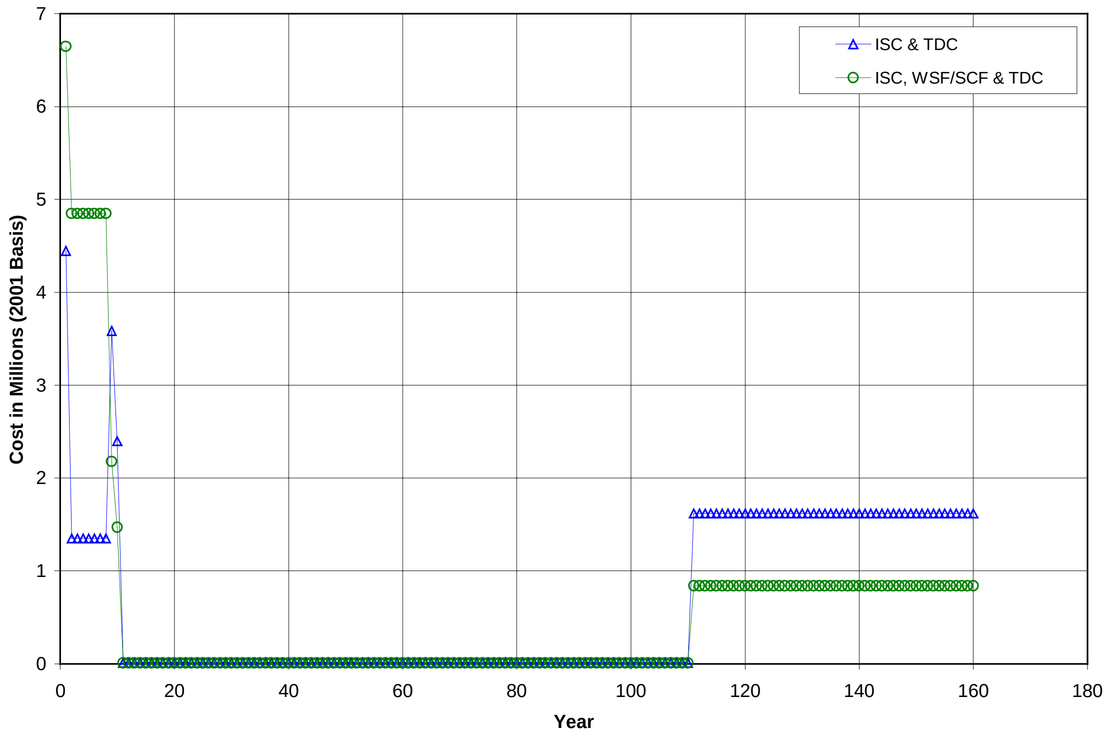

Figure 11. Cost Timeline with Traditional Subsidence Repair

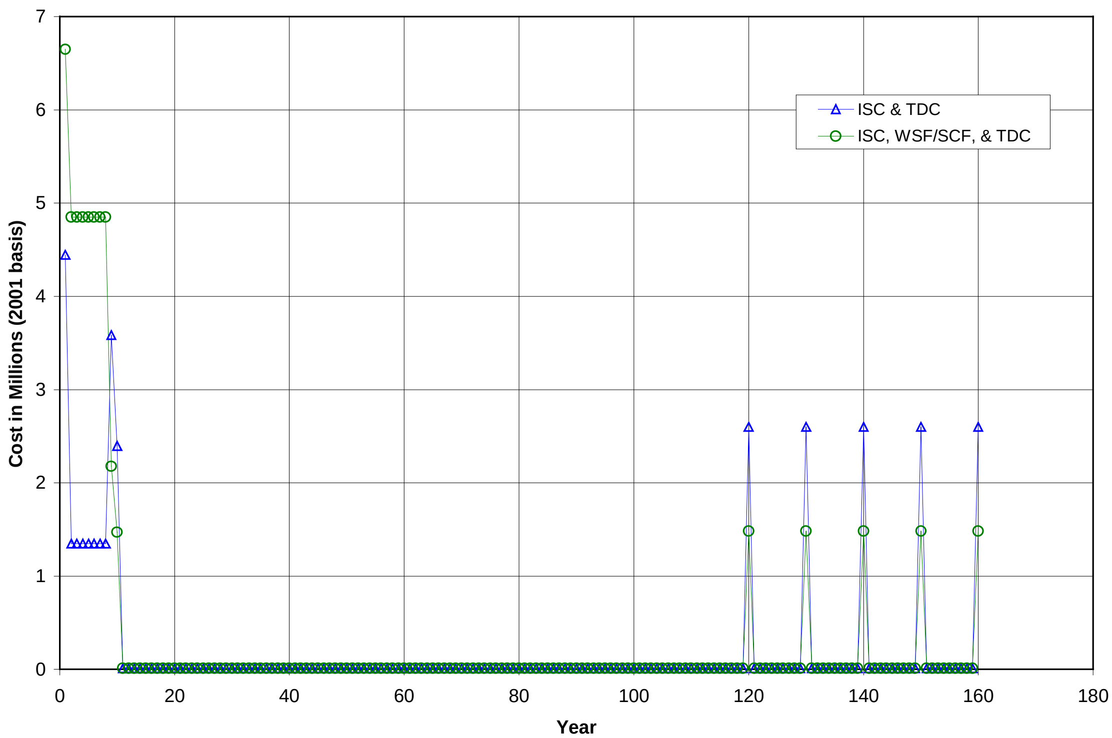

Figure 12. Cost Timeline with Cap Replacement Subsidence Repair

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7.0 RECOMMENDATIONS

Based upon the results of this evaluation, it is recommended that the following waste/subsidence treatment cases, which were evaluated within this report, be eliminated from further consideration:

- No action (i.e., the use of an interim soil cover alone)
- Use of the Waste Sort Facility/Super Compactor Facility as the only means of waste/subsidence treatment
- Use of standard dynamic compaction as a means of waste/subsidence treatment

Of the waste/subsidence treatment cases evaluated within this report, it is recommended that the following two receive further consideration:

- Use of tertiary dynamic compaction
- Combined use of the Waste Sort Facility/Super Compactor Facility and tertiary dynamic compaction

It is recommended that further consideration of these two cases should be based primarily upon Solid Waste Division decisions related to long-term maintenance. From closure cost and subsidence potential reduction perspective, the use of tertiary dynamic compaction alone is the most cost efficient method evaluated in this report. However, from a long-term maintenance and subsidence potential perspective, the optimum choice between the two is not clear.

Basically, long-term maintenance strategies that result in lower long-term maintenance costs favor the tertiary dynamic compaction case, but traditional long-term maintenance strategies which result in higher long-term maintenance costs favor the combined use of the Waste Sort Facility/Super Compactor Facility and tertiary dynamic compaction. Therefore, it is recommended that long-term maintenance strategies (i.e. primarily subsidence repair strategies) be evaluated relative to waste/subsidence treatment strategies, and that additional waste/subsidence treatments be included in the evaluation in order to produce the most technically effective and cost efficient strategy for implementation.

The following are items of further note relative to the comparison between the use of tertiary dynamic compaction alone and the combined use of the Waste Sort Facility/Super Compactor Facility and tertiary dynamic compaction:

- Within this evaluation the combined use of the Waste Sort Facility/Super Compactor Facility and tertiary dynamic compaction only resulted in an additional subsidence potential reduction of 4 percent (seven inches) over that of tertiary dynamic compaction alone, which produced a reduction of 52 percent. Therefore, the addition of the Waste Sort Facility/Super Compactor Facility to tertiary dynamic compaction does not appear to be very effective in providing additional subsidence potential reduction. However, in terms of long-term maintenance cost, this combined use was seen to be potentially more cost effective than tertiary dynamic compaction alone, because it resulted in a slightly greater subsidence potential reduction and involved an Engineered Trench with a smaller surface area by a factor of 1.72. This demonstrates that any waste/subsidence treatment, which will produce greater subsidence potential reductions and involves a smaller surface area, will result in lower long-term maintenance costs.

- The dynamic compaction performed to date at SRS has not been optimized to obtain the most compaction reasonably achievable. Such optimization could potentially produce additional subsidence potential reduction over that estimated in this report. Such optimization would need to be based upon both modeling and field studies, and may of course cost more than the standard and tertiary dynamic compaction methodologies outlined here. Dynamic compaction optimization could be realized through both the modification of the dynamic compaction methodology and the timing of dynamic compaction relative to the corrosion and subsequent strength reduction of B-25 boxes.
- The greatest uncertainties of this study are associated with the long-term subsidence repair methods and costs and with the timing of B-25 box corrosion and collapse (i.e. time until Engineered Trench stabilization). Both of these items greatly impact the cost therefore further study and evaluation of each is recommended to reduce the uncertainty.

Based upon this evaluation, it is also recommended that Solid Waste Division evaluate the potentially negative aspects of B-25 usage versus the benefits of B-25 usage, for the disposal of waste in Engineered Trenches. The following are the potentially negative aspects of B-25 usage from a subsidence perspective identified in this report:

- Use of B-25 boxes for the disposal of relatively low-density waste results in a large inherent subsidence potential, which can not be significantly eliminated by any of the waste/subsidence treatment methods evaluated.
- B-25 box use also results in a period assumed in this study of 150 to 300 years prior to complete Engineered Trench stabilization, due to the slow rate of buried B-25 box corrosion. This may increase the period of required institutional control over that currently assumed.
- B-25 box use in this evaluation was directly responsible for high B-25 box, WSF/SCF, and subsidence repair costs.

It is recommended that the Solid Waste Division consider the following alternatives to B-25 box use:

- Soft-sided bags: It is recommended that the Solid Waste Division continue to support the development of soft-sided bags as a potential replacement for B-25 boxes.
- Waste Sort Facility/Super Compactor Facility use with direct ‘uncontainerized’ disposal of the resulting waste pucks and uncompactable waste (soft-sided bags might be used with the uncompactable waste fraction). Alternately, a cylindrical overpack could be used for the pucks.
- Direct disposal of all waste and operation similar to a sanitary landfill. Other alternatives should also be investigated which will produce greater subsidence potential reductions and involve a smaller trench surface area, and therefore result in lower long-term maintenance costs.

If the Solid Waste Division determines that the positive aspects of B-25 box usage outweigh the negative for disposal of relatively low-density waste in Engineered Trenches, it is recommended that the following be considered:

- Continuation of B-25 box corrosion studies so that the timing associated with buried B-25 box structural collapse can be more accurately determined.
- Evaluation of additional waste/subsidence treatment methods, which can potentially reduce the subsidence potential more than those methods evaluated in this report.
- Evaluations of alternative capping designs/strategies that can better handle significant differential subsidence over an extended time period.
- Evaluation of alternative long-term maintenance strategies (i.e. primarily subsidence repair strategies) in order to determine the most technically effective and cost efficient strategy for implementation.
- The following options should be considered in the combined evaluation of additional waste/subsidence treatment methods, alternative capping designs/strategies, and alternative long-term maintenance strategies:
    - Dynamic compaction optimization for stacked B-25 boxes: This could consider compaction energies, compaction patterns, compaction timing relative to B-25 box corrosion, etc.
    - Use of a temporary low permeability barrier followed by dynamic compaction when the buried B-25 boxes begin to collapse, followed by installation of a final cover.
    - Placement of interim soil layers between each layer of B-25 boxes.

The following are additional recommendations:

- Based upon this evaluation, it is recommended that the Solid Waste Division focus their cost savings efforts on the B-25 boxes, the WSF/SCF, and long-term subsidence repair, since these are the elements identified as having the greatest costs.
- It is recommended that the Solid Waste Division continue to support the work outlined in SRT-WED-2001-00001, Program Plan for Evaluating Trench Disposal of Uncompacted Job Control Waste, (Butcher, et al., 2001) including the following:
    - Cost Study: Treatment vs Long Term Cap Maintenance (i.e., It is recommended that this cost study be expanded as outlined above)
    - Evaluation of Trench Usage and Alternate Disposal Containers (i.e. soft-sided bags)
    - Evaluation of Alternative Waste Stabilization and Closure Strategies (i.e. TTP SR11SS29, Long-Term Waste Stabilization Design for Long-Term Cover Systems funded by the DOE Subsurface Contaminant Focus Area)

Overall the Solid Waste Division should take an integrated approach which considers the implications of and interactions between disposal operations, waste/subsidence treatments, closure methodology, and long-term maintenance requirements in order to produce an overall strategy which is both technically effective and cost efficient.

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APPENDIX A

CALCULATIONS

LIST OF FIGURES

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A-1 Engineered Trench Filled with WSF/SCF Processed B-25s
Number of B-25s and B-25 Density Calculations

Assumptions:

- 29.7% of waste containers do not pass the WSF screening criteria (Roddy, 2001b). The average density of uncompacted B-25 boxes that do not pass the WSF screening criteria is 0.2124 g/cm^3 (Wilhite, 2001a) (Table 4).
- 70.3% of waste containers do pass the WSF screening criteria (Roddy, 2001b). The average density of uncompacted B-25 boxes that pass the WSF screening criteria is 0.1673 g/cm^3 (Wilhite, 2001a) (Table 4).
- Of the 70.3% of the waste containers that pass the WSF screening criteria, about 15% fail the SCF compaction criteria and are not supercompacted (Wilhite, 2001b).
- The average weight of B-25 boxes, including the box itself, that pass the WSF screening criteria but fail the SCF compaction criteria is 748,430 g (1650 lbs $\times$ 453.5924 g/lb) (Thomas, 2001).
- The average weight of SRS B-25 boxes is 262,520 g (Wilhite, 2001c).
- On the average, 40 supercompacted drums are contained in a B-25 box (Roddy, 2001a).
- On average, an empty 55-gallon drum weighs 16,330 g (36 lbs $\times$ 453.5924 g/lb) (Roddy, 2001a).
- The average volume of a B-25 box is 2,550,000 cm^3 (90 ft3 $\times$ 28,316.85 cm^3/ft^3) (Dames & Moore, 1987).
- The average density of B-25 boxes containing supercompacted waste is 0.7201 g/cm^3 and it is assumed that this does not vary whether or not the waste drums were received directly from the generators at the SCF (Wilhite, 2001a) (Table 4).
- The 779 supercompacted SRS B-25 boxes of Table 4 contained 6095 compacted 55-gallon drums of waste that were received directly from the generators at the SCF ready for compaction and therefore were not processed through the WSF. It is assumed that these numbers accurately represent the ratio of compacted 55-gallon drums of waste received directly from the generators to those processed through the WSF. The waste received directly from the generators ready for supercompaction is assumed to have the same density as the waste, which is processed through the WSF/SCF and then supercompacted. (Wilhite, 2001e)

Calculations based upon 100 B-25 boxes received:

- 70.3 B-25 boxes pass the WSF screening criteria, and they have an average density of 0.1673 g/cm^3.
- 29.7 B-25 boxes do not pass the WSF screening criteria, and they have an average density of 0.2124 g/cm^3.
- Of the 70.3 B-25 boxes that pass the WSF screening criteria, 15% fail the SCF compaction criteria and are rejected for Super Compaction:
  - Number of B-25s not suitable for Super Compaction = $0.15 \times 70.3 = 10.5$
  - Number of B-25s suitable for Super Compaction = $70.3 - 10.5 = 59.8$
- 10.5 boxes pass the WSF screening criteria but fail the SCF compaction criteria, and they have an average density of 0.1906 g/cm^3, as determined below:

$$\text{Average density} = \frac{(748{,}430\text{ g} - 262{,}520\text{ g})}{2{,}550{,}000\text{ cm}^3}$$

$$= 0.1906\text{ g/cm}^3$$

- 59.8 boxes pass the WSF screening criteria and pass the SCF compaction criteria and are subsequently supercompacted, and they have an average density of 0.1632 g/cm^3, as determined below:

$$\text{Average density} = \frac{(70.3 \times 0.1673\text{ g/cm}^3) - (10.5 \times 0.1906\text{ g/cm}^3)}{59.8}$$

$$= 0.1632\text{ g/cm}^3$$

- Total number of uncompacted B-25s = $29.7 + 10.5 = 40.2$
- Density of total uncompacted B-25s = $\frac{(29.7 \times 0.2124\text{ g/cm}^3) + (10.5 \times 0.1906\text{ g/cm}^3)}{(29.7 + 10.5)}$

$$= 0.2067\text{ g/cm}^3$$

- Result of the Super Compaction of the 59.8 B-25 boxes suitable for Super Compaction:

  - Average waste mass in each of the 59.8 B-25s = $0.1632\ g/cm^3 \times 2{,}550{,}000\ cm^3$
    = 416,160 g

  - Average waste/drum mass per supercompacted B-25 = $0.7201 g/cm^3 \times 2{,}550{,}000\ cm^3$
    = 1,836,255 g

  - Average drum mass per supercompacted B-25 = $40 \times 16{,}330$ g
    = 653,200 g

  - Average drum density per supercompacted B-25 = $653{,}200\ g \div 2{,}550{,}000\ cm^3$
    = $0.2562\ g/cm^3$

  - Average waste mass per supercompacted B-25 = 1,836,255 g – 653,200 g
    = 1,183,055 g

  - The ratio of the number of original uncompacted B-25s to the resulting number of supercompacted B-25s after compaction is equal to the average supercompacted B-25 waste mass to the average waste mass in the original 59.8 B-25s prior to Super Compaction:

    Ratio = 1,183,055 g ÷ 416,160 g = 2.843

  - Number of supercompacted B-25s resulting from the Super Compaction of the 59.8 original uncompacted B-25s:

  - Number of supercompacted B-25s = 59.8 ÷ 2.843
    = 21.0

- Result of the receipt of 55-gallon drums of waste directly from the generators at the SCF, ready for compaction without processing through the WSF:

  - The 779 supercompacted SRS B-25 boxes of Table 4 contained 6095 compacted 55-gallon drums of waste that were received directly from the generators at the SCF ready for compaction and therefore were not processed through the WSF.

  - Total number of drums in the 779 supercompacted SRS B-25 boxes $= 779 \times 40$

    $= 31,16$

  - % of drums received directly from generators $= (6095 \div 31,160) \times 100$

    $= 19.56\%$

  - The receipt of 100 B-25 Boxes for WSF screening results in the production of 21 supercompacted B-25 boxes as calculated above.

  - % of supercompacted drums containing waste processed through WSF $= 100 - 19.56$

    $= 80.44\%$

  - Number of drums contained in the 21 supercompacted B-25 boxes processed through WSF: Number of drums $= 21 \times 40$

    $= 840$

  - 840 drums represent 80.44% of the drums in supercompacted B-25 boxes for the option of 100 B-25 boxes received for WSF screening.

  - Total number of drums in supercompacted B-25 boxes for the option of 100 B-25 boxes received for WSF screening:

    Number of drums $= 1044 - 840$

    $= 204$

- Equivalent number of supercompacted B-25s based upon the 204 drums received directly from generators at SCF without processing through WSF for the option of 100 B-25 boxes received for WSF screening:

  Equivalent number of supercompacted B-25s $= 204 \div 40$

  $= 5.1$

- Equivalent number of uncompacted B-25s to the 5.1 supercompacted produced from the 204 55-gallon drums received directly from generators without processing through WSF:

  Equivalent number of uncompacted B-25s 5.1×2.843

  $= 14.5$

- Average density of B-25 boxes with WSF/SCF processing followed by disposal in the Engineered Trench:

  Average density $= \dfrac{(21.0 \times 0.7201 \text{ g/cm}^3) + (5.1 \times 0.7201 \text{ g/cm}^3) + (40.2 \times 0.2067 \text{ g/cm}^3)}{(21.0 + 5.1 + 40.2)}$

  $= 0.4088 \text{ g/cm}^3$

- Total number of supercompacted B-25s $= 21.0 + 5.1$

  $= 26.1$

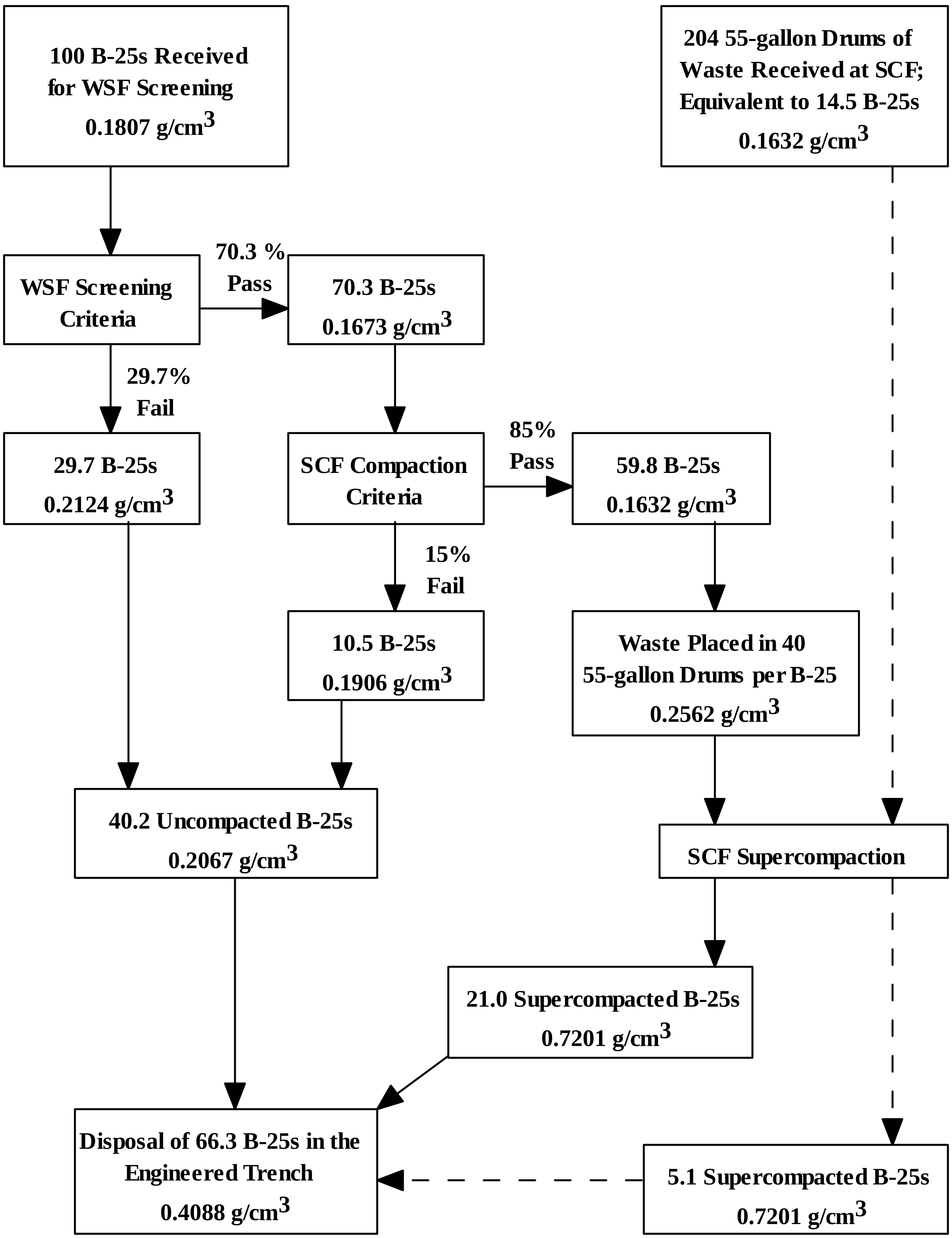

Figure A-1. WSF/SCF Process Flow Diagram

A-2 Engineered Trench Filled with only Uncompacted B-25s
Number of B-25s and B-25 Density Calculations

Assumptions:

- Based upon the receipt of 100 B-25 boxes for WSF screening the following assumptions are made:
  - 29.7% of waste containers do not pass the WSF screening criteria (Roddy, 2001b). The average density of uncompacted B-25 boxes that do not pass the WSF screening criteria is 0.2124 g/cm^3 (Wilhite, 2001a) (Table 4).
  - 70.3% of waste containers do pass the WSF screening criteria (Roddy, 2001b). The average density of uncompacted B-25 boxes that pass the WSF screening criteria is 0.1673 g/cm^3 (Wilhite, 2001a) (Table 4).
- For every 100 B-25 boxes received for WSF screening, an equivalent of 14.5 uncompacted, B-25 boxes are received directly from generators without processing through WSF. The average density of the equivalent uncompacted B-25 boxes received directly from generators is 0.1632 g/cm^3 (Table 4).
- The WSF/SCF is not utilized and all of the boxes are placed directly in the Engineered Trench without any Super Compaction.

Calculations based upon 100 B-25 boxes received:

- 70.3 B-25 boxes that currently pass the WSF screening criteria have an average density of 0.1673 g/cm^3, and are placed directly in the Engineered Trench without processing through the WSF/SCF.
- 29.7 B-25 boxes that currently do not pass the WSF screening criteria have an average density of 0.2124 g/cm^3, and are placed directly in the Engineered Trench.
- Average density of uncompacted B-25s processed through WSF

$$\text{Average density} = \frac{(70.3 \times 0.1673\ \text{g/cm}^3) + (29.7 \times 0.2124\ \text{g/cm}^3)}{(70.3 + 29.7)}$$

$$= 0.1807\ \text{g/cm}^3$$

- An equivalent 14.5 uncompacted B-25 boxes received directly from the generators have an average density of 0.1632 g/cm^3, and are placed directly in the Engineered Trench.

$$\text{Average density of all uncompacted B-25 boxes} = \frac{(100 \times 0.1807) + (14.5 \times 0.1632)}{(100 + 14.5)}$$

$$= 0.1785\ \text{g/cm}^3$$

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A-3 Engineered Trench Mass Equivalency Calculations
WSF/SCF Processed B-25s versus Uncompacted Only B-25s

Assumptions:

- Based upon previous calculations, the average density of B-25s in Engineered Trenches containing only uncompacted B-25s is 0.1785 g/cm^3.
- Based upon previous calculations, the average density of B-25s in Engineered Trenches containing B-25s processed through WSF/SCF is 0.4088 g/cm^3. For every 26.1 supercompacted B-25 boxes at an average density of 0.7201 g/cm^3 there are 40.2 uncompacted B-25 boxes at an average density of 0.2067 g/cm^3.
- Based upon previous calculations the average waste mass per supercompacted B-25s is 1,183,055 g.

Equivalency calculations:

- Average waste mass per uncompacted B-25 box in Engineered Trenches containing only uncompacted B-25s:

  Average B-25 waste mass $= 0.1785\ \text{g/cm}^3 \times 2{,}550{,}000\ \text{cm}^3$

  $= 455{,}175\ \text{g}$

- Average waste mass per uncompacted B-25 box in Engineered Trenches containing B-25s processed through WSF/SCF:

  Average B-25 waste mass $= 0.2067\ \text{g/cm}^3 \times 2{,}550{,}000\ \text{cm}^3$

  $= 527{,}085\ \text{g}$

- Average waste mass per average B-25 box (i.e. based upon the ratio of uncompacted and supercompacted B-25 boxes) in Engineered Trenches containing B-25s processed through WSF/SCF:

  Average B-25 waste mass $= \dfrac{(1{,}183{,}055\ \text{g} \times 26.1) + (527{,}085\ \text{g} \times 40.2)}{(26.1 + 40.2)}$

  $= 785{,}318\ \text{g}$

- Mass equivalency of an average B-25 Box in Engineered Trenches containing B-25s processed through WSF/SCF to that in Engineered Trenches containing only uncompacted B-25s (i.e. not processed through the WSF/SCF):

  Mass equivalency $= 785{,}318\ \text{g} \div 455{,}175\ \text{g} = 1.72$

  That is, 1.72 B-25 boxes in an Engineered Trench containing only uncompacted B-25s is equivalent on a mass basis to 1 box in an Engineered Trench containing B-25s which have been processed through the WSF/SCF.

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A-4 Relative Subsidence Potential Reduction Calculations

Figure A-2 provides the basis for all subsidence potential reduction calculations:

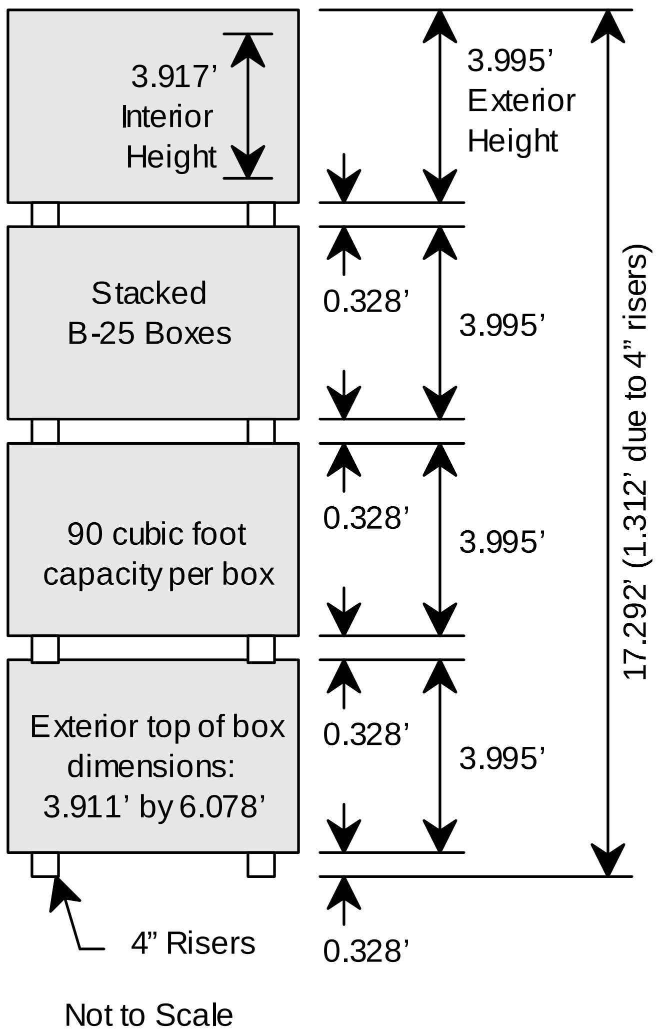


Figure A-2. B-25 Boxes, Stacked Four High

(Dames & Moore, 1987)

I. Subsidence Potential of Stacked Uncompacted B-25 Boxes Prior to Placement of the Interim Cover

Assumptions:

- The subsidence potential of the risers is assumed to be 1.312 feet (4×0.328 ft).
- Based upon a previous calculation, the average density of uncompacted B-25s, where the B-25s are not processed through the WSF/SCF but are placed directly in the Engineered Trench without any Super Compaction, is 0.1785 g/cm^3.
- It is assumed that the B-25s/waste will eventually compact to an average bulk density of 1.5 g/cm^3, which is within the range of typical soil densities and slightly below the measured E-Area/Burial Grounds soil bulk densities:
  - Hillel (1982) provides a soil bulk density range of 1.1 to 1.6 g/cm^3 for natural soils.
  - Lambe and Whitman (1969) provide a bulk density range of 1.4 to 2.0 g/cm^3 (87 to 127 pcf) for silty sand.
  - Table A-1 provides the results of measured soil bulk densities within E-Area and the Burial Grounds. The average soil bulk density is approximately 1.6 g/cm^3.

Subsidence Potential Calculation:

$$\text{Subsidence Potential} = \left(4 \times \frac{1.5\ \text{g/cm}^3 - 0.1785\ \text{g/cm}^3}{1.5\ \text{g/cm}^3} \times 3.917\ \text{ft}\right) + 1.312\ \text{ft}$$

$$= 15.116\ \text{ft}$$

Table A-1 Measured Soil Bulk Densities

Sample	Sample Location	Depth (ft)	Dry Bulk Density (pcf)	Dry Bulk Density (g/cm^3)
AT-8	E-Area	4.0-6	113.8	1.82
AT-8	E-Area	13-15	113.9	1.82
AT-8	E-Area	28-30	101.9	1.63
AT-8	E-Area	41-43	99.1	1.59
AT-North	E-Area	2.0-4	115.5	1.85
AT-North	E-Area	9.0-11	97.1	1.55
AT-North	E-Area	14-16	97.1	1.55
AT-North	E-Area	18-20	98.3	1.57
AT-North	E-Area	23-25	103.0	1.65
AT-North	E-Area	42-44	98.4	1.57
AT-North	E-Area	51-53	92.9	1.49
AT-North	E-Area	59-61	105.3	1.68
AT-South	E-Area	2-2.5	107.4	1.72
AT-South	E-Area	14-15	99.1	1.59
AT-South	E-Area	16-17.5	100.1	1.60
AT-South	E-Area	38-40	112.3	1.80
AT-South	E-Area	43-45	85.7	1.37
VL-1	E-Area	1.5-3.5	107.5	1.72
VL-1	E-Area	13-15	95.5	1.53
VL-1	E-Area	21-23	97.5	1.56
VL-1	E-Area	27-29	87.5	1.40
VL-1	E-Area	29-31	90.5	1.45
VL-1	E-Area	31-33	104.5	1.67
VL-1	E-Area	44-46	99.0	1.58
VL-1	E-Area	54-56	93.5	1.50
ST5	E-Area	20-21.9	101.8	1.63
ST6	E-Area	23-25	90.6	1.45
ST8	E-Area	41-43	97.8	1.57
ST11	E-Area	64-65.2	99.1	1.59
BGST-01-01	Burial Grounds	9-10.75	118.8	1.90
BGST-01-02	Burial Grounds	19-20.7	97.0	1.55
BGST-01-03	Burial Grounds	29-31	99.0	1.58
BGST-01-04	Burial Grounds	39	97.7	1.56
BGST-01-04	Burial Grounds	40	100.5	1.61
BGST-02-01	Burial Grounds	8.8-9.8	108.3	1.73
BGST-02-02	Burial Grounds	19-21	108.2	1.73
BGST-02-03	Burial Grounds	29-31	104.2	1.67
BGST-02-04	Burial Grounds	39-41	106.7	1.71
BGST-03-01	Burial Grounds	9-10.65	106.8	1.71
BGST-03-02	Burial Grounds	19-21	103.7	1.66
BGST-03-03	Burial Grounds	29-31	93.3	1.49
BGST-03-04	Burial Grounds	39-41	110.6	1.77
		Average	101.4	1.62
		Median	99.6	1.59
		Minimum	85.7	1.37
		Maximum	118.8	1.90

II. Subsidence Potential of Stacked Uncompacted B-25 Boxes after Placement of the Interim Cover

Assumptions:

- Based upon the Yau (1986), Dames & Moore (1987), and Jones, et al. (2001) studies, when the interim soil cover is placed over the stacked uncompacted boxes with a bulldozer, the lid of the box will collapse into the box itself. Thus, it is assumed that the lid of uncompacted B-25s will collapse on average 1.5 feet into the top box when the interim soil cover is placed with a bulldozer.
- It is assumed that the subsidence potential of this case is equal to the subsidence potential of stacked uncompacted B-25 boxes prior to placement of the interim cover minus the assumed average collapse of the lid of the top box.

Subsidence Potential Calculation:

Subsidence Potential = 15.116 ft – 1.5 ft

= 13.616 ft

III. Subsidence Potential of Stacked Supercompacted B-25 Boxes after Placement of the Interim Cover

Assumptions:

- Based upon the Yau (1986), Dames & Moore (1987), and Jones, et al. (2001) studies, it is assumed that the lid of uncompacted B-25s will collapse on average 1.5 feet into the box when the interim soil cover is placed with a bulldozer.
- It is assumed that the crushed 55-gallon drums inside a supercompacted B-25 are stacked to within 6 inches of the box lid. Therefore on average placement of the interim soil cover can only collapse the lid of the top box 3 inches (0.25 ft) into the box itself due to the curvature produced during lid deformation and collapse.
- Based upon a previous calculation, for every 26.1 supercompacted boxes placed in the Engineered Trench at an average density of 0.7201 g/cm^3, 40.2 uncompacted boxes are placed in the trench at an average density of 0.2067 g/cm^3.
- Based upon a previous calculation, the average density of B-25s placed in an Engineered Trench after processing through the WSF/SCF is 0.4088 g/cm^3.
- Random placement of uncompacted and supercompacted B-25 boxes is assumed.

Subsidence Potential Calculations:

- Percentage of supercompacted B-25s placed in the trench $= (26.1 \div (26.1 + 40.2)) \times 100$
  $= 39.4\%$

- Percentage of uncompacted B-25s placed in the trench $= 100\% - 39.4\%$
  $= 60.6\%$

- Subsidence potential reduction due to placement of the interim soil cover:

  Subsidence Potential Reduction $= (0.394 \times 0.25 \text{ ft}) + (0.606 \times 1.5 \text{ ft})$
  $= 1.008 \text{ ft}$

- Subsidence potential due to average density of B-25s in the trench:

  Subsidence Potential $= \left(4 \times \dfrac{1.5 \text{ g/cm}^3 - 0.4088 \text{ g/cm}^3}{1.5 \text{ g/cm}^3} \times 3.917 \text{ ft}\right) + 1.312 \text{ ft}$
  $= 12.710 \text{ ft}$

- Total Subsidence Potential $= 12.710 \text{ ft} - 1.008 \text{ ft}$
  $= 11.702 \text{ ft}$

IV. Subsidence Potential of Stacked Uncompacted B-25 Boxes after Placement of the Interim Cover followed by Dynamic Compaction

Assumptions:

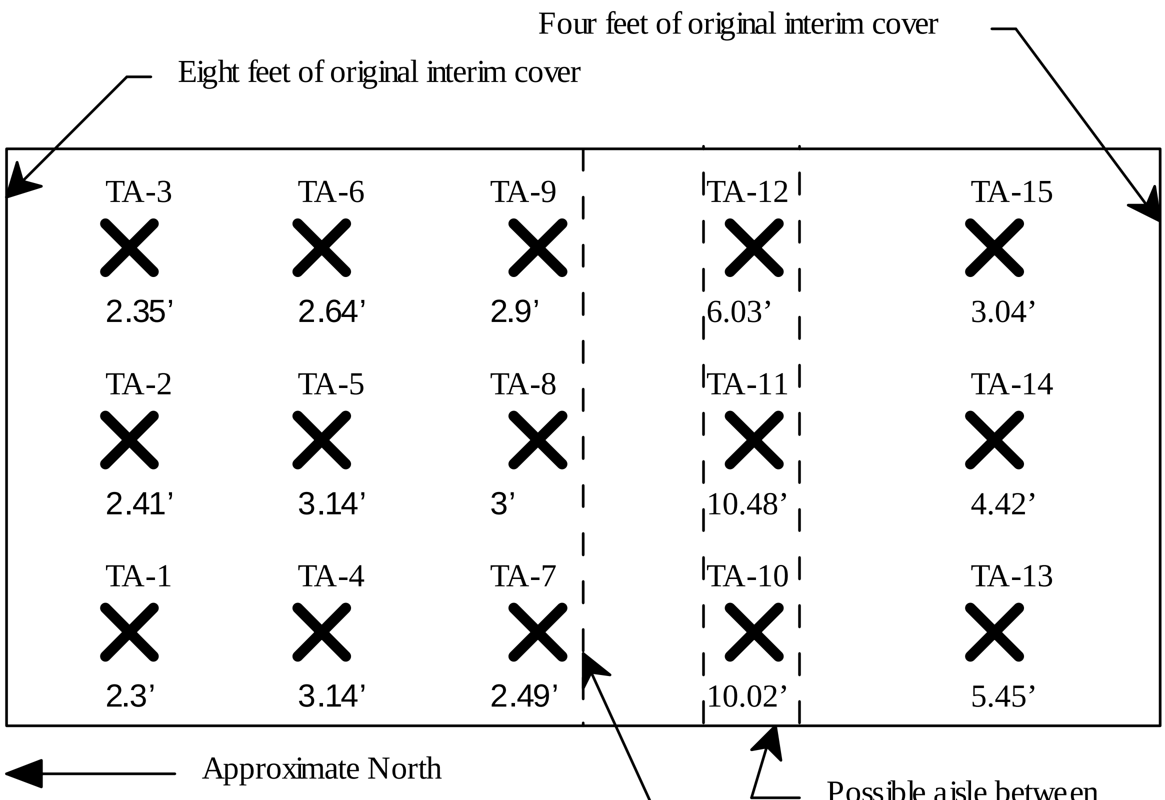
- The initial subsidence potential of stacked uncompacted B-25 boxes prior to interim cover placement is 15.092 feet as determined in a previous calculation.
- Based upon the Yau (1986), Dames & Moore (1987), and Jones, et al. (2001) studies, it is assumed that the lid of uncompacted B-25s will collapse on average 1.5 feet into the box when the interim soil cover is placed with a bulldozer.
- The assumed performance of dynamic compaction of the Engineered Trench will be based upon the actual results of the dynamic compaction of Engineered Low-Level Trench #1 (ELLT-1) that was conducted during closure of the Mixed Waste Management Facility (MWMF). Based upon Phifer, 1991 and Phifer and Serrato, 2000, the dynamic compaction of ELLT-1 produced 5 to 6 foot craters in an average of 12 drops of the eight foot diameter, 20 ton weight. It will be assumed that dynamic compaction produces an average 5.5 foot crater.

- Standard dynamic compaction as conducted on ELLT-1 is conducted on a 10-foot square grid pattern using both primary and secondary drops of an 8-foot diameter weight to provide compaction within the center of each grid square. However, this means that only 50% of the surface area of ELLT-1 was treated with standard dynamic compaction:

Area of weight	$= ¼ \pi D^2 = ¼ \pi (8\ ft)^2$ $= 50.3\ ft^2$
Area of grid square	$= 10\ ft \times 10\ ft$ $= 100\ ft^2$
Percent of Area Treated	$= (50.3\ ft^2 \div 100\ ft^2) \times 100$ $= 50.3\ \%$

- Tertiary dynamic compaction is also conducted on a 10-foot square grid pattern using primary, secondary, and tertiary drops of an 8-foot diameter weight to provide compaction within the center and at the intersection of each grid square. This tertiary dynamic compaction pattern provides essentially 100% treatment of the entire surface area.
- It will also be assumed that the reduction in subsidence potential produced by the ELLT-1 static surcharge program, which was conducted prior to the dynamic compaction of ELLT-1, could have also been eliminated by dynamic compaction. Therefore, the results of the ELLT-1 static surcharge will be added to the ELLT-1 dynamic compaction results to obtain the total subsidence potential reduction produced by the use of dynamic compaction.
- The following information was obtained from C. T. Main, 1989a; C. T. Main, 1989b; and Phifer, 1991 in reference to the MWMF static surcharge program:
  - The static surcharge was performed on Engineered Low-Level Trench #1 (ELLT-1).
  - Only the results from the northern two thirds of ELLT-1 will be considered for these calculations, since it was determined that the static surcharge results from the southern third of ELLT-1 was affected by an aisle space that resulted in excessive subsidence as noted on the following sketch.
  - The average measured subsidence produced by the static surcharge was 2.7 feet over the northern two thirds of ELLT-1:

    Subsidence = (2.35’ + 2.41’ + 2.3’ + 2.64’ + 3.14’ + 3.14’ + 2.9’ + 3’ + 2.49’) ÷ 9
  - The average interim soil cover over the northern two thirds of ELLT-1 was approximately seven feet.
- It is assumed that the interim soil cover is on average 7 feet thick and consists of silty sand (SM) with a bulk density of 90 pcf prior to static surcharge and that a bulk density of 110 pcf is produced after static surcharge.
- It is assumed that dynamic compaction is conducted with an average 6 foot thick interim soil cover, and that dynamic compaction takes the interim soil cover bulk density from 110 pcf to 120 pcf. The soil cover was graded after the static surcharge test to produce an average 6-foot thick soil cover.



Notes:
- Not to scale
- Values are the measured subsidence
- Average measured subsidence = 2.7 ft over the northern two thirds of ELLT-1
- Average interim soil cover = 7 ft over the northern two thirds of ELLT-1

Figure A-3. ELLT-1 Static Surcharge Test Results

(C. T. Main, 1989a)

Subsidence Potential Calculations (for both standard and tertiary dynamic compaction):

- Subsidence potential reduction due to placement of the interim soil cover:

  Subsidence Potential Reduction = 1.5 ft (see assumptions)

- Subsidence potential reduction due to generic static surcharge (i.e. not yet considering percentage of surface area treated):

  Average Measured Subsidence = 2.7 ft (see assumptions)

  Subsidence due to Soil Consolidation $= \dfrac{110\text{ pcf} - 90\text{ pcf}}{110\text{ pcf}} \times 7\text{ ft}$
  $= 1.273$ ft

  Subsidence Potential Reduction $= 2.7\text{ ft} - 1.273\text{ ft}$
  $= 1.427\text{ ft} = 50.3\ \%$

  Subsidence Potential Reduction $= 2.7\text{ ft} - 1.273\text{ ft}$
  $= 1.427$ ft

  This subsidence potential reduction could have been due almost entirely to the collapse of the risers into the box tops and soil (i.e. 1.312 ft of subsidence potential due to the risers).

- Subsidence potential reduction due to generic dynamic compaction (i.e. not yet considering percentage of surface area treated):

  Average Measured Subsidence = 5.5 ft (see assumptions)

  Subsidence due to Soil Consolidation $= \dfrac{120\text{ pcf} - 110\text{ pcf}}{120\text{ pcf}} \times 6\text{ ft}$
  $= 0.5$ ft

  Subsidence Potential Reduction $= 5.5\text{ ft} - 0.5\text{ ft}$
  $= 5.0$ ft

- Subsidence potential reduction due to standard dynamic compaction:

  Initial subsidence potential of an Engineered Trench containing only uncompacted B-25s:

Initial Subsidence Potential	= 15.116 ft (see assumptions)
Interim Soil Cover Placement Subsidence Potential Reduction	= 1.5 ft (see assumptions)
Percentage of Area Treated	= 50% (see assumptions)
Static Surcharge Subsidence Potential Reduction	$= 0.50 \times 1.427$ ft = 0.714 ft
Standard Dynamic Compaction Subsidence Potential Reduction	$= 0.50 \times 5.0$ ft = 2.5 ft
Total Subsidence Potential	= 15.116 ft – 1.5 ft – 0.714 ft – 2.5 ft = 10.402 ft

- Subsidence potential reduction due to tertiary dynamic compaction:

  Initial subsidence potential of an Engineered Trench containing only uncompacted B-25:

Initial Subsidence Potential	= 15.116 ft (see assumptions)
Interim Soil Cover Placement Subsidence Potential Reduction	= 1.5 ft (see assumptions)
Percentage of Area Treated	= 100% (see assumptions)
Static Surcharge Subsidence Potential Reduction	$= 1 \times 1.427$ ft = 1.427 ft
Standard Dynamic Compaction Subsidence Potential Reduction	$= 1 \times 5.0$ ft = 5.0 ft
Total Subsidence Potential	= 15.116 ft – 1.5 ft – 1.427 ft – 5.0 ft = 7.189 ft

V. Subsidence Potential of Stacked Supercompacted B-25 Boxes after Placement of the Interim Soil Cover followed by Dynamic Compaction

Assumptions:

- The stacked supercompacted B-25 box subsidence potential after interim soil cover placement is 11.702 feet as determined in a previous calculation. This subsidence potential includes the reduction due to the collapse of the top box's lid during interim soil cover placement. This includes a 1.5-foot reduction for uncompacted boxes and a 0.25 reduction for supercompacted boxes.
- It is assumed that the crushed 55-gallon drums inside a supercompacted B-25 are stacked to within 6 inches of the box lid. It is assumed that dynamic compaction can eliminate this 6-inch (0.5-foot) void. However, upon elimination of this 6-inch void, the crushed drums within the supercompacted B-25 form columns which prohibit further dynamic compaction of the box.
- It is also assumed that dynamic compaction can eliminate the entire void space of 1.312 feet due to the risers.
- The maximum subsidence potential reduction that can be produced from the dynamic compaction of a stack of uncompacted B-25 boxes is 6.427 feet (1.427 ft + 5.0 ft), based on a previous calculation.
- Based upon previous assumptions, standard dynamic compaction treats 50% of the area and tertiary dynamic compaction treats 100% of the area.
- Based upon a previous calculation, an Engineered Trench containing boxes processed through the WSF/SCF contains 39.4% supercompacted boxes and 60.6% uncompacted boxes.
- Random placement of uncompacted and supercompacted B-25 boxes is assumed.

Subsidence Potential Calculations (for both standard and tertiary dynamic compaction):

- The maximum subsidence potential reduction that can be produced from the dynamic compaction of a stack of supercompacted B-25 boxes is as follows. The 0.25-foot reduction has already been accounted for in the initial subsidence potential of stacked supercompacted B-25 boxes after interim soil cover placement due to the collapse of the top box's lid during interim soil cover placement.

Maximum Subsidence Potential Reduction	$= ((4 \times 0.5 \text{ ft}) - 0.25 \text{ ft}) + 1.312 \text{ ft}$
	$= 3.062 \text{ ft}$

- Subsidence potential reduction due to standard dynamic compaction:

Initial Subsidence Potential of an Engineered Trench containing B-25s processed through the WSF/SCF after placement of the interim cover	= 11.702 ft (see assumptions)
Percentage of Area Treated	= 50% (see assumptions)
Maximum Subsidence Potential Reduction due to dynamic compaction for a Stack of Uncompacted B-25s	= 6.427 ft (see assumptions)
Maximum Subsidence Potential Reduction due to dynamic compaction for a Stack of Supercompacted B-25s	= 3.062 ft
Total Subsidence Potential	$= 11.702 \text{ ft} - (0.5 \times ((0.606 \times 6.427 \text{ ft}) + (0.394 \times 3.062 \text{ ft})))$
	$= 9.151 \text{ ft}$

- Subsidence potential reduction due to tertiary dynamic compaction:

Initial Subsidence Potential of an Engineered Trench containing B-25s processed through the WSF/SCF after placement of the interim cover	= 11.702 ft (see assumptions)
Percentage of Area Treated	= 100% (see assumptions)
Maximum Subsidence Potential Reduction due to dynamic compaction for a Stack of Uncompacted B-25s	= 6.427 ft (see assumptions)
Maximum Subsidence Potential Reduction due to dynamic compaction for a Stack of Supercompacted B-25s	= 3.062 ft
Total Subsidence Potential	$= 11.702 \text{ ft} - (1 \times ((0.606 \times 6.427 \text{ ft}) + (0.394 \times 3.062 \text{ ft})))$
	$= 6.601 \text{ ft}$

VI. Subsidence Potential Summary and Subsidence Potential Reduction Calculations

Table A-2. Estimated Relative Subsidence Potential and Subsidence Potential Reduction

Subsidence Treatment Method	Estimated Relative Subsidence Potential (ft)	Estimated Relative Subsidence Potential Reduction (%)
Base Subsidence Potential [1]	15.116	$= \frac{(15.116 - 15.116)}{15.116} \times 100$ $= 0$
ISC	13.616	$= \frac{(15.116 - 13.616)}{15.116} \times 100$ $= 9.9$
ISC and WSF/SCF	11.702	$= \frac{(15.116 - 11.702)}{15.116} \times 100$ $= 22.6$
ISC and SDC	10.402	$= \frac{(15.116 - 10.402)}{15.116} \times 100$ $= 31.2$
ISC and TDC	7.189	$= \frac{(15.116 - 7.189)}{15.116} \times 100$ $= 52.4$
ISC, WSF/SCF, and SDC	9.151	$= \frac{(15.116 - 9.151)}{15.116} \times 100$ $= 39.5$
ISC, WSF/SCF, and TDC	6.601	$= \frac{(15.116 - 6.601)}{15.116} \times 100$ $= 56.3$

[1] Subsidence Potential of a stack of four uncompacted B-25 boxes prior to the placement of the interim soil cover
ISC = Interim Soil Cover
WSF/SCF = Waste Sort Facility / Super Compactor Facility
SDC = Standard Dynamic Compaction
TDC = Tertiary Dynamic Compaction

A-5 Relative Cost of Engineered Trench Design and Construction

Assumptions:

- An Engineered Trench design to contain 12,000 B-25 boxes measures 150 feet by 650 feet at the top by 22 feet deep (Wilhite, 2000a; Wilhite, 2000b; Wilhite, 2001d).
- Such an Engineered Trench costs $1,800,000 to design and construct in year 2001 dollars (Bunker, 2001d).
- Based upon previous calculations, 1.72 B-25 boxes in an Engineered Trench containing only uncompacted B-25s is equivalent on a mass basis to 1 box in an Engineered Trench containing B-25s, which have been processed through the WSF/SCF.
- An Engineered Trench containing B-25s, which have been processed through the WSF/SCF, will be taken as containing 12,000 B-25 boxes stacked four high (Wilhite, 2001d) and will be taken as having a surface area of 97,500 ft^2 (150 feet × 650 feet).
- A direct linear relationship is assumed between cost and the number of B-25s to be disposed for each case under consideration.

Design and Construction Cost Calculations:

- Cost of Engineered Trench design and construction for one 12,000 B-25 Box Engineered Trench for disposal of B-25s processed through the WSF/SCF:

Design and Construction Cost	= $1,800,000

- Cost of Engineered Trench design and construction for one 20,640 B-25 Box Engineered Trench for disposal of B-25s not processed through the WSF/SCF:

Mass equivalent number of B-25s	= 12,000 boxes × 1.72
	= 20,640 boxes
Mass equivalent surface area	= (150 ft × 650 ft) × 1.72
	= 167,700 ft^2
Design and Construction Cost	= $1,800,000 × 1.72
	= $3,096,000

An Engineered Trench containing B-25s, which have not been processed through the WSF/SCF, will be taken as containing 20,640 B-25 boxes stacked four high and will be taken as having a surface area of 167,700 ft^2.

Design and Construction Cost Summary:

Table A-3. Relative Cost of Engineered Trench Design and Construction

Subsistence Treatment Method	Number of B-25 Boxes Disposed	Relative Engineered Trench Design and Construction Cost ($)
ISC	20,640	3,096,000
ISC and WSF/SCF	12,000	1,800,000
ISC and SDC	20,640	3,096,000
ISC and TDC	20,640	3,096,000
ISC, WSF/SCF, and SDC	12,000	1,800,000
ISC, WSF/SCF, and TDC	12,000	1,800,000

ISC = Interim Soil Cover
WSF/SCF = Waste Sort Facility / Super Compactor Facility
SDC = Standard Dynamic Compaction
TDC = Tertiary Dynamic Compaction

A-6 Relative Cost of Waste/Subsidence Treatment

Assumptions:

- Based upon a previous assumption and calculation, an Engineered Trench containing B-25s, which have been processed through the WSF/SCF, will be taken as containing 12,000 B-25 boxes stacked four high (Wilhite, 2001d) and will be taken as having a surface area of 2.24 acres (97,500 $ft^2 \div$ 43,560 ft^2/acre).
- Based upon a previous assumption and calculation, an Engineered Trench containing B-25s, which have not been processed through the WSF/SCF, will be taken as containing 20,640 B-25 boxes stacked four high and will be taken as having a surface area of 3.85 acres (167,700 $ft^2 \div$ 43,560 ft^2/acre). This produces a mass equivalent comparison to cases that do involve processing through the WSF/SCF.
- Each B-25 box costs $523 (Bunker, 2001b).
- Based upon a previous calculation, an Engineered Trench containing boxes processed through the WSF/SCF contains 39.4% supercompacted boxes and 60.6% uncompacted boxes.
- Information in Table A-4 was obtained from Gary Bunker and LeRoy Williams relative to the cost per each supercompacted B-25 box:

Table A-4. Cost Per Each Supercompacted B-25 Box

Parameter	FY01	FY02	FY03	FY04	Total
Estimated Number of Supercompacted B-25s [1]	772	643	649	449	2513
WSF ($) [2]	2,610,000	2,610,000	2,610,000	2,610,000	10,440,000
SCF ($)[2]	1,710,000	1,710,000	1,710,000	1,710,000	6,840,000
Total ($)[2]	4,320,000	4,320,000	4,320,000	4,320,000	17,280,000

WSF = Waste Sort Facility
SCF = Super Compactor Facility
[1] Williams, 2001a; Williams, 2001b
[2] Bunker, 2001a

- Based upon past SRS experience (1998) the subcontractor costs for performance of standard dynamic compaction has been estimated at $100,000 for mobilization/demobilization plus $200,000 per acre (Phifer and Serrato, 2000).

- The total Standard Dynamic Compaction cost is assumed to be 2 times the subcontractor cost to account for the indirect cost.
- Standard dynamic compaction treats only 50% of the area whereas tertiary dynamic compaction treats 100% of the area. Therefore, since standard dynamic compaction has been estimated to cost $200,000 per acre, tertiary dynamic compaction will be assumed to cost $400,000 per acre. Mobilization/demobilization costs will be assumed to remain at $100,000 for tertiary dynamic compaction. (Phifer and Serrato, 2000).
- The total Tertiary Dynamic Compaction cost is assumed to be 2 times the subcontractor cost to account for the indirect cost.

Subsidence Treatment Costs Calculations:

- Table A-5 shows the calculated B-25 box cost for each case:

Table A-5. Calculated B-25 Box Cost for Each Case

Subsidence Treatment	Number of B-25s	Calculated B-25 Box Cost ($)
ISC	20,640	$= 20{,}640 \times \$523$ $= \$10{,}794{,}720$
ISC and WSF/SCF	12,000	$= 12{,}000 \times \$523$ $= \$6{,}276{,}000$
ISC and SDC	20,640	$= 20{,}640 \times \$523$ $= \$10{,}794{,}720$
ISC and TDC	20,640	$= 20{,}640 \times \$523$ $= \$10{,}794{,}720$
ISC, WSF/SCF, and SDC	12,000	$= 12{,}000 \times \$523$ $= \$6{,}276{,}000$
ISC, WSF/SCF, and TDC	12,000	$= 12{,}000 \times \$523$ $= \$6{,}276{,}000$

- Number of supercompacted boxes in an Engineered Trench containing B-25s, which have been processed through the WSF/SCF:

Number of B-25s	= 12,000
Percentage of Supercompacted B-25s	= 39.4%
Number of Supercompacted Boxes	= $0.394 \times 12{,}000$ boxes
	= 4,728 boxes

- Cost per supercompacted B-25:

Estimated WSF/SCF Cost over a Four-Year Period	= \$17,280,000
Estimated Number of Supercompacted Boxes Produced over a Four-Year Period	= 2513
Cost per Supercompacted B-25	= \$17,280,000 ÷ 2513
	= \$6,876 / supercompacted B-25 box

- Table A-6 shows the calculated WSF/SCF subsidence treatment costs for each case.

Table A-6. Calculated WSF/SCF Subsidence Treatment Costs

Subsidence Treatment	Number of Super-compacted B-25s	Calculated WSF/SCF Subsidence Treatment cost (\$)
ISC	0	= 0 × \$6,876 = \$0
ISC and WSF/SCF	4,728	= 4,728 × \$6,876 = \$32,509,728
ISC and SDC	0	= 0 × \$ = \$0
ISC and TDC	0	= 0 × \$ = \$0
ISC, WSF/SCF, and SDC	4,728	= 4,728 × \$6,876 = \$32,509,728
ISC, WSF/SCF, and TDC	4,728	= 4,728 × \$6,876 = \$32,509,728

- Table A-7 shows the calculated dynamic compaction treatment costs for each case. The dynamic compaction costs have been escalated from 1998 to 2001 based upon a yearly 3% inflation rate (3 years at a F/P factor of 1.0927 (Grant, et al., 1976)).

Table A-7. Calculated Dynamic Compaction Treatment Costs

Subsidence Treatment	Engineered Trench Surface Area (acres)	Calculated Dynamic Compaction Subsidence Treatment Cost ($)
ISC	3.85	0
ISC and WSF/SCF	2.24	0
ISC and SDC	3.85	$= (2 \times (\$100,000 + (3.85\text{ ac} \times \$200,000/\text{ac}))) \times 1.0927$ $= \$1,901,298$
ISC and TDC	3.85	$= (2 \times (\$100,000 + (3.85\text{ ac} \times \$400,000/\text{ac}))) \times 1.0927$ $= \$3,584,056$
ISC, WSF/SCF, and SDC	2.24	$= (2 \times (\$100,000 + (2.24\text{ ac} \times \$200,000/\text{ac}))) \times 1.0927$ $= \$1,197,599$
ISC, WSF/SCF, and TDC	2.24	$= (2 \times (\$100,000 + (2.24\text{ ac} \times \$400,000/\text{ac}))) \times 1.0927$ $= \$2,176,658$

Subsidence Treatment Costs Summary:

Table A-8. Subsistence Treatment Costs Summary Cost Tables

Subsidence Treatment	Waste Mass Equivalent Number of B-25s	Number of Super-compacted B-25s	Engineered Trench Surface Area (acres)
ISC	20,640	0	3.85
ISC and WSF/SCF	12,000	4,728	2.24
ISC and SDC	20,640	0	3.85
ISC and TDC	20,640	0	3.85
ISC, WSF/SCF, and SDC	12,000	4,728	2.24
ISC, WSF/SCF, and TDC	12,000	4,728	2.24

Subsidence Treatment	B-25 Box Cost ($)	WSF/SCF Cost ($)	Dynamic Compaction Cost ($)	Relative Subsidence Treatment Cost ($)
ISC	10,794,720	0	0	10,794,720
ISC and WSF/SCF	6,276,000	32,509,728	0	38,785,728
ISC and SDC	10,794,720	0	1,901,298	12,696,018
ISC and TDC	10,794,720	0	3,584,056	14,378,776
ISC, WSF/SCF, and SDC	6,276,000	32,509,728	1,197,599	39,983,327
ISC, WSF/SCF, and TDC	6,276,000	32,509,728	2,176,658	40,962,386

ISC = Interim Soil Cover
WSF/SCF = Waste Sort Facility / Super Compactor Facility
SDC = Standard Dynamic Compaction
TDC = Tertiary Dynamic Compaction

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A-7 Relative Cost of Closure Cap

Assumptions:

- Based upon a previous assumption and calculation, an Engineered Trench containing B-25s, which have been processed through the WSF/SCF, will be taken as having surface area dimensions of 150 feet by 650 feet. (Wilhite, 2000a; Wilhite, 2000b)
- Based upon a previous assumption and calculation, an Engineered Trench containing B-25s, which have not been processed through the WSF/SCF, will be taken as having a surface area of 167,700 ft^2, which is equivalent to having surface area dimensions of 258 feet by 650 feet. This produces a mass equivalent comparison to cases that do involve processing through the WSF/SCF.
- The closure cap surface area will be greater than the Engineered Trench surface area it covers. It is assumed that the closure cap extends 10 feet in all directions beyond the actual Engineered Trench.
- It is assumed that the closure cap over the Engineered Trench will consist of a high density polyethylene (HDPE), flexible membrane liner (FML) over a geosynthetic clay liner (GCL) over a clayey sand foundation layer per Figure A-4.
- A direct linear relationship is assumed between cost and the acreage of the closure cap.
- It is assumed that the cost of the FML/GCL closure caps can be determined from the estimated closure cap construction costs of a 2 and 5 acre cap as determined from a 1993 study (Bhutani, et al., 1993). Table A-9 presents the costs for a 2 and 5 acre FML/GCL closure cap. The costs have been modified from those of the 1993 study to exclude site preparation, waste stabilization, fencing, and monitor well costs. These excluded costs, except for waste stabilization, are assumed to not be applicable due to existing E-Area infrastructure. The waste stabilization costs were estimated in a previous calculation.

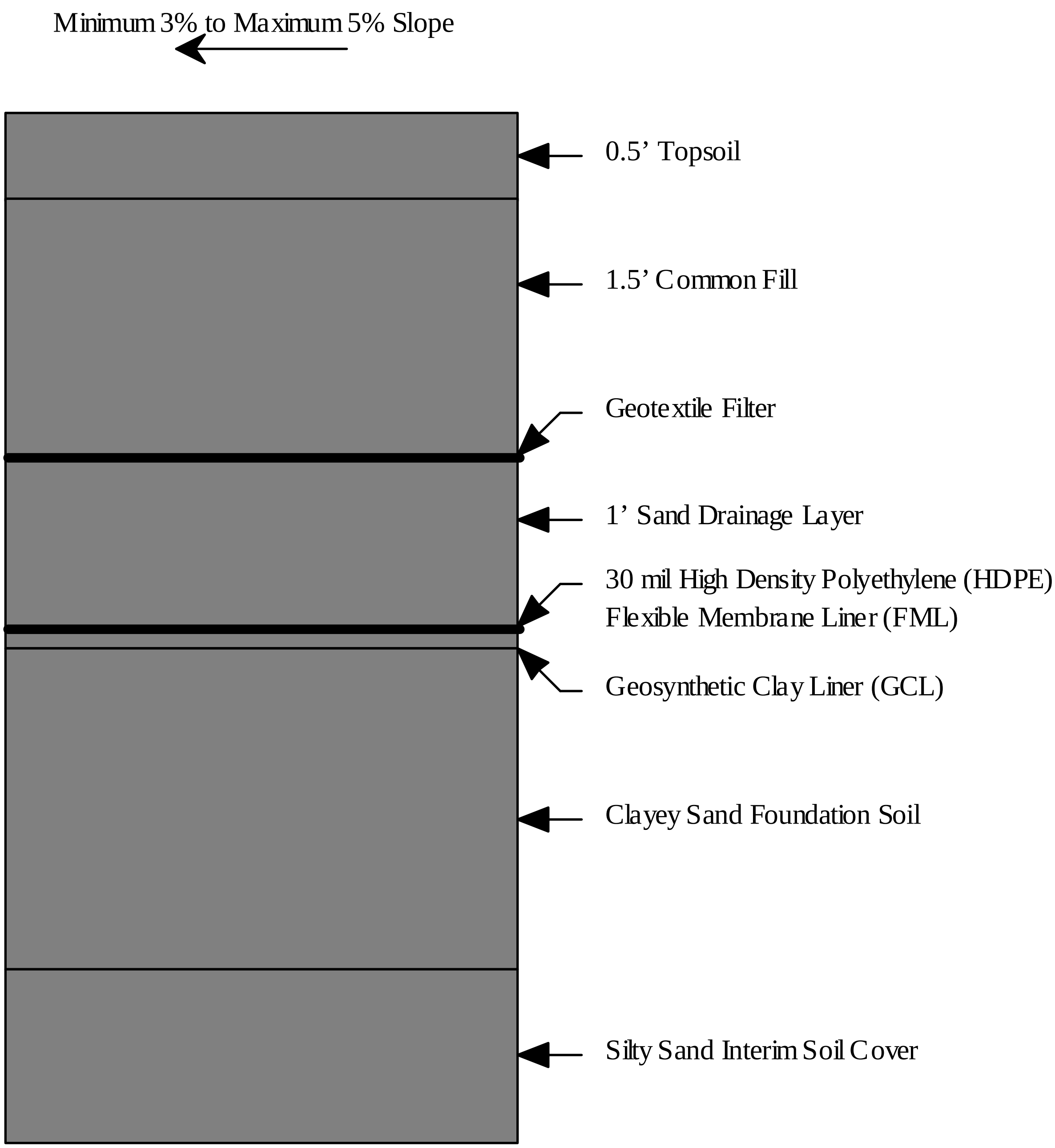

Figure A-4. FML/GCL Closure Cap Configuration
(Modified from Bhutani, et al., 1993)

Table A-9. FML/GCL Closure Cap Construction Estimates

Closure Cap Construction Activity	1993 2-Acre FML/GCL [1] Cover ($)	1993 5-Acre FML/GCL Cover ($)
Site Pre-contouring	3,000	4,330
Foundation Soil Placement	65,040	162,610
GCL Placement	80,800	200,200
FML Placement	39,420	98,580
Drainage Layer Placement	47,920	119,790
Geotextile Filter Placement	3,790	9,460
Common Fill Placement	25,740	64,360
Topsoil Placement	20,130	50,270
Perimeter Drainage Layer Placement	2,760	4,290
Drainage Ditch Construction	4,010	10,030
Seeding, Fertilizing, & Mulching	13,320	33,300
Cover and Subsidence Marker Survey	2,400	3,600
Direct Cost Subtotal	308,330	760,820
Clean up & Demobilization (5% of Direct Cost Subtotal)	15,416	38,041
Location Factor (40% of Direct Cost Subtotal)	123,332	304,328
Total Direct Cost	447,078	1,103,189
Indirect Costs (100% of Direct Costs)	447,078	1,103,189
Total Closure Cap Construction Cost	894,156	2,206,378

[1] FML/GCL = high density polyethylene (HDPE), flexible membrane liner (FML) over a geosynthetic clay liner (GCL) over a clayey sand foundation layer.

Closure Cap Costs Calculations:

- Acreage of an Engineered Trench containing B-25s, which have been processed through the WSF/SCF:

Engineered Trench Surface Area Dimensions	= 150 ft by 650 ft
Closure Cap Surface Area Dimensions	= 170 ft (150 ft + 20 ft) by 670 ft (650 ft + 20 ft)
Closure Cap Acreage	= (170 ft $\times$ 670 ft) $\div$ 43,560 ft^2/acre
	= 2.61 acres

- Acreage of an Engineered Trench containing B-25s, which have not been processed through the WSF/SCF:

Engineered Trench Surface Area Dimensions	= 258 ft by 650 ft
Closure Cap Surface Area Dimensions	= 278 ft (258 ft + 20 ft) by 670 ft (650 ft + 20 ft)
Closure Cap Acreage	= (278 ft $\times$ 670 ft) $\div$ 43,560 ft^2/acre
	= 4.28 acres

- Cost of a closure cap over an Engineered Trench containing B-25s, which have been processed through the WSF/SCF:

Closure Cap Acreage = 2.61 acres

The cost has been escalated from 1993 to 2001 based upon a yearly 3% inflation rate (8 years at a F/P factor of 1.2668 (Grant, et al., 1976)

Closure Cap Cost

$$= 1.2668 \times (\$894{,}156 + ((\$2{,}206{,}378 - \$894{,}156) \times \frac{(2.61 - 2)}{(5 - 2)}))$$

$$= \$1{,}470{,}722$$

- Cost of a closure cap over an Engineered Trench containing B-25s, which have not been processed through the WSF/SCF:

Closure Cap Acreage = 4.28 acres

The cost has been escalated from 1993 to 2001 based upon a yearly 3% inflation rate (8 years at a F/P factor of 1.2668 (Grant, et al., 1976)

Closure Cap Cost

$$= 1.2668 \times (\$894{,}156 + ((\$2{,}206{,}378 - \$894{,}156) \times \frac{(4.28 - 2)}{(5 - 2)}))$$

$$= \$2{,}396{,}082$$

Closure Cap Costs Summary:

Table A-10. Closure Cap Costs Summary

Subsidence Treatment	Closure Cap Surface Area (acres)	Relative FML/GCL Closure Cap Cost ($)
ISC	4.28	2,396,082
ISC and WSF/SCF	2.61	1,470,722
ISC and SDC	4.28	2,396,082
ISC and TDC	4.28	2,396,082
ISC, WSF/SCF, and SDC	2.61	1,470,722
ISC, WSF/SCF, and TDC	2.61	1,470,722

ISC = Interim Soil Cover
WSF/SCF = Waste Sort Facility / Super Compactor Facility
SDC = Standard Dynamic Compaction
TDC = Tertiary Dynamic Compaction

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A-8 Relative Cost of Closure Cap Subsidence Repair – Traditional Method

Assumptions:

- Preliminary results from the exhumation of the B-25 box on May 3, 2001, indicated that very little corrosion of the box occurred over an eight year burial period (Jones, et al., 2001).
- Dynamic compaction can result in the breakage of the protective coating bond away from the metal resulting in the increased potential for corrosion (McMullin and Dendler, 1994).
- For B-25s that are not dynamically compacted a period of B-25 box structural collapse (i.e. a subsidence period) has been assumed to be from 200 to 300 years after burial.
- For B-25s that are dynamically compacted, a period of B-25 box structural collapse (i.e. a subsidence period) has been assumed to be from 100 to 150 years after burial and dynamic compaction.
- It is assumed that subsidence will occur over the entire surface area of the closure cap, which is directly over the Engineered Trench, over the subsidence period.
- It is assumed that the number of repair events per area will be proportional to the subsidence potential. It is further assumed that every four feet of subsidence will produce a condition, requiring repair. Therefore, the number of repair events is assumed to equal the estimated relative subsidence potential divided by four feet. It is assumed that fractions of 4 feet will also require repair due to the extended nature of the subsidence periods.
- It is assumed that the closure cap over the Engineered Trench will consist of a high-density polyethylene (HDPE), flexible membrane liner (FML) over a geosynthetic clay liner (GCL) over a clayey sand foundation layer.
- A repair cost of $\$266/ft^2$ for a FML/GCL closure cap will be assumed. This cost is based upon the $\$210/ft^2$ repair cost for a FML/GCL closure cap estimated by Bhutani, et al., in 1993, and escalation from 1993 to 2001 based upon a yearly 3% inflation rate (8 years at a F/P factor of 1.2668) (Grant, et al., 1976).

  FML/GCL Closure Cap Repair Cost $= \$210/ft^2 \times 1.2668$

  $= \$266/ft^2$

- The Relative Cap Subsidence Repair Cost is assumed to equal the following:

  Repair Cost $= \$266/ft^2 \times$ Number of Repair Events $\times$ Surface Area (ft^2)

- The following table provides the estimated relative subsidence potential, assumed subsidence period, and the surface area of the Engineered Trench. The values in the table are based upon previous calculations and assumptions.

Table A-11. Closure Cap Subsidence Repair Cost Parameters

Subsidence Treatment	Relative Subsidence Potential (ft)	Subsidence Period (years)	Engineered Trench Surface Area (ft^2)
ISC	13.616	200 to 300	167,700
ISC and WSF/SCF	11.702	200 to 300	97,500
ISC and SDC	10.402	100 to 150	167,700
ISC and TDC	7.189	100 to 150	167,700
ISC, WSF/SCF, and SDC	9.151	100 to 150	97,500
ISC, WSF/SCF, and TDC	6.601	100 to 150	97,500

Closure Cap Subsidence Repair Costs Calculations:

- The number of repair events has been calculated by dividing the estimated relative subsidence potential by four feet in Table A-12.

Table A-12. Number of Repair Events

Subsidence Treatment	Relative Subsidence Potential (ft)	Number of Repair Events
ISC	13.616	13.616 ft ÷ 4 ft = 3.4
ISC and WSF/SCF	11.702	11.702 ft ÷ 4 ft = 2.9
ISC and SDC	10.402	10.402 ft ÷ 4 ft = 2.6
ISC and TDC	7.189	7.189 ft ÷ 4 ft = 1.8
ISC, WSF/SCF, and SDC	9.151	9.151 ft ÷ 4 ft = 2.3
ISC, WSF/SCF, and TDC	6.601	6.601 ft ÷ 4 ft = 1.6

- The Relative Cap Subsidence Repair Cost has been calculated in Table A-13 based upon the following formula:
  Repair Cost = $\$266/\ ft^2 \times$ Number of Repair Events $\times$ Surface Area (ft^2)

Table A-13. Relative Cap Subsidence Repair Cost

Subsidence Treatment	Number of Repair Events	Engineered Trench Surface Area (ft^2)	Relative Closure Cap Subsidence Repair Cost - Traditional Method ($)
ISC	3.4	167,700	$= \$266/\ ft^2 \times 3.4 \times 167{,}700\ ft^2$ = $151,667,880
ISC and WSF/SCF	2.9	97,500	$= \$266/\ ft^2 \times 2.9 \times 97{,}500\ ft^2$ = $75,211,500
ISC and SDC	2.6	167,700	$= \$266/\ ft^2 \times 2.6 \times 167{,}700\ ft^2$ = $115,981,320
ISC and TDC	1.8	167,700	$= \$266/\ ft^2 \times 1.8 \times 167{,}700\ ft^2$ = $80,294,760
ISC, WSF/SCF, and SDC	2.3	97,500	$= \$266/\ ft^2 \times 2.3 \times 97{,}500\ ft^2$ = $59,650,500
ISC, WSF/SCF, and TDC	1.6	97,500	$= \$266/\ ft^2 \times 1.6 \times 97{,}500\ ft^2$ = $41,496,000

Table A-14. Closure Cap Subsidence Repair Costs Summary:

Subsidence Treatment	Relative Closure Cap Subsidence Repair Cost - Traditional Method ($)
ISC	151,667,880
ISC and WSF/SCF	75,211,500
ISC and SDC	115,981,320
ISC and TDC	80,294,760
ISC, WSF/SCF, and SDC	59,650,500
ISC, WSF/SCF, and TDC	41,496,000

ISC = Interim Soil Cover - WSF/SCF = Waste Sort Facility / Super Compactor Facility
SDC = Standard Dynamic Compaction - TDC = Tertiary Dynamic Compaction

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A-9 Relative Cost of Closure Cap Subsidence Repair – Cap Replacement Method

Assumptions:

- Preliminary results from the exhumation of the B-25 box on May 3, 2001 indicated that very little corrosion of the box occurred over an eight year burial period (Jones, et al., 2001).
- Dynamic compaction can result in the breakage of the protective coating bond away from the metal resulting in the increased potential for corrosion (McMullin and Dendler, 1994).
- For B-25s that are not dynamically compacted, a period of B-25 box structural collapse (i.e. a subsidence period) has been assumed to be from 200 to 300 years after burial.
- For B-25s that are dynamically compacted, a period of B-25 box structural collapse (i.e. a subsidence period) has been assumed to be from 100 to 150 years after burial and dynamic compaction.
- It is assumed that the closure cap over the Engineered Trench will consist of a high-density polyethylene (HDPE), flexible membrane liner (FML) over a geosynthetic clay liner (GCL) over a clayey sand foundation layer.
- It is assumed that subsidence will occur over the entire surface area of the closure cap, which is directly over the Engineered Trench, over the subsidence period.
- It is assumed that rather than repairing the closure cap at each subsidence event, as done under the traditional methodology, the following will be performed:
  - Subsidence holes will be filled in with soil to maintain the grade and promote runoff as they occur. The costs associated with this activity are considered to be covered in the cost estimate for the cap replacements, since these costs include site pre-contouring and foundation soil placement costs.
  - The entire cap will be replaced periodically during the duration of subsidence. The frequency of cap replacement will be based upon the relative subsidence potential associated with each case. It is assumed that the cap replacement frequency varies inversely with relative subsidence potential. The cap replacement frequency for the ISC, WSF/SCF, and TDC case will be assumed to be 10 years; all other cap replacement frequencies will be determined based upon this case. The old cap will not be removed, but a new cap will be placed directly on top of the old cap.
- Based upon a previous calculation, the cost of a 4.28-acre FML/GCL closure cap is assumed to be $2,396,082 and the cost of a 2.61-acre cap is assumed to be $1,470722.
- The following table provides the relative subsidence potential, subsidence period, and the closure cap surface area. The values in the table are based upon previous calculations and assumptions.

Table A-15. Closure Cap Subsidence Repair Cost Parameters

Subsidence Treatment	Subsidence Period (years)	Relative Subsidence Potential (ft)	Closure Cap Surface Area (acres)
ISC	200 to 300	13.616	4.28
ISC and WSF/SCF	200 to 300	11.702	2.61
ISC and SDC	100 to 150	10.402	4.28
ISC and TDC	100 to 150	7.189	4.28
ISC, WSF/SCF, and SDC	100 to 150	9.151	2.61
ISC, WSF/SCF, and TDC	100 to 150	6.601	2.61

Closure Cap Subsidence Repair Costs Calculations:

Table A-16 through Table A-19 provide a summary of the closure cap subsidence repair costs.

Table A-16. Assumed Duration of Subsidence During Which the Cap Will Be Replaced

Subsidence Treatment	Subsidence Period (years)	Duration of Subsidence (years)
ISC	200 to 300	300 – 200 = 100
ISC and WSF/SCF	200 to 300	300 – 200 = 100
ISC and SDC	100 to 150	150 – 100 = 50
ISC and TDC	100 to 150	150 – 100 = 50
ISC, WSF/SCF, and SDC	100 to 150	150 – 100 = 50
ISC, WSF/SCF, and TDC	100 to 150	150 – 100 = 50

Table A-17. Cap Replacement Frequency

Subsidence Treatment	Relative Subsidence Potential (ft)	Cap Replacement Frequency (years)
ISC	13.616	= (6.601 ft ÷ 13.616 ft) 10 years = 4.8 years
ISC and WSF/SCF	11.702	= (6.601 ft ÷ 11.702 ft) 10 years =5.6 years
ISC and SDC	10.402	= (6.601 ft ÷ 10.402 ft) 10 years = 6.3 years
ISC and TDC	7.189	= (6.601 ft ÷ 7.189 ft) 10 years = 9.2 years
ISC, WSF/SCF, and SDC	9.151	= (6.601 ft ÷ 9.151 ft) 10 years = 7.2 years
ISC, WSF/SCF, and TDC	6.601	10 years assumed

Table A-18. Number of Cap Replacements

Subsidence Treatment	Duration of Subsidence (years)	Cap Replacement Frequency (years)	Number of Replacement Caps
ISC	100	4.8	= 100 ÷ 4.8 = 20.8
ISC and WSF/SCF	100	5.6	= 100 ÷ 5.6 = 17.8
ISC and SDC	50	6.3	= 50 ÷ 6.3 = 7.9
ISC and TDC	50	9.2	= 50 ÷ 9.2 = 5.4
ISC, WSF/SCF, and SDC	50	7.2	= 50 ÷ 7.2 = 6.9
ISC, WSF/SCF, and TDC	50	10	= 50 ÷ 10 = 5

Table A-19. Cost of Cap Replacement

Subsidence Treatment	Number of Replacement Caps	Cost per Replacement Cap ($)	Relative Cap Subsidence Repair Cost - Cap Replacement Method ($)
ISC	20.8	2,396,082	$= 20.8 \times 2{,}396{,}082$ $= 49{,}838{,}506$
ISC and WSF/SCF	17.8	1,470,722	$= 17.8 \times 1{,}470{,}722$ $= 26{,}178{,}851$
ISC and SDC	7.9	2,396,082	$= 7.9 \times 2{,}396{,}082$ $= 18{,}929{,}048$
ISC and TDC	5.4	2,396,082	$= 5.4 \times 2{,}396{,}082$ $= 12{,}938{,}843$
ISC, WSF/SCF, and SDC	6.9	1,470,722	$= 6.9 \times 1{,}470{,}722$ $= 10{,}147{,}982$
ISC, WSF/SCF, and TDC	5	1,470,722	$= 5 \times 1{,}470{,}722$ $= 7{,}353{,}610$

Closure Cap Subsidence Repair Costs Summary:

- The cap subsidence repair costs from both the traditional method and the cap replacement method are presented in Table A-20. These costs are assumed to represent the range of possible closure cap, subsidence repair costs based upon the capping and repair strategy implemented.
- The traditional method of closure cap subsidence repair is based on the typical requirements associated with RCRA/CERCLA closure caps. This method consists of closure cap repair immediately after each subsidence event occurs, during the anticipated duration of subsidence.
- The cap replacement method consists of filling subsidence holes with soil to maintain the grade and promote runoff as they occur and of replacing the entire closure cap periodically during the duration of subsidence at a frequency based upon the relative subsidence potential associated with each case. The old cap will not be removed, but a new cap will be placed directly on top of the old cap.

Table A-20. Cap Subsidence Repair Costs

Subsidence Treatment	Relative Cap Subsidence Repair Cost - Traditional Method ($)	Relative Cap Subsidence Repair Cost - Cap Replacement Method ($)	Traditional Method to Cap Replacement Method Ratio [1]
ISC	151,667,880	49,838,506	3.0
ISC and WSF/SCF	75,211,500	26,178,851	2.9
ISC and SDC	115,981,320	18,929,048	6.1
ISC and TDC	80,294,760	12,938,843	6.2
ISC, WSF/SCF, and SDC	59,650,500	10,147,982	5.9
ISC, WSF/SCF, and TDC	41,496,000	7,353,610	5.6

[1] Ratio = Traditional Method Cost ÷ Cap Replacement Method Cost
ISC = Interim Soil Cover
WSF/SCF = Waste Sort Facility / Super Compactor Facility
SDC = Standard Dynamic Compaction
TDC = Tertiary Dynamic Compaction

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A-10 Relative Cost of Cumulative Operating and Maintenance

Assumptions:

- Based upon previous calculations and assumptions, the closure cap over an Engineered Trench containing B-25s, which have been processed through the WSF/SCF, has a surface area of 2.61 acres.
- Based upon previous calculations and assumptions, the closure cap over an Engineered Trench containing B-25s, which have not been processed through the WSF/SCF, has a surface area of 4.28 acres.
- It is assumed that Operating and Maintenance (O&M) costs will be incurred until the subsidence period for each case has been completed.
- For B-25s that are not dynamically compacted, a period of B-25 box structural collapse (i.e. a subsidence period) has been assumed to be from 200 to 300 years after burial.
- For B-25s that are dynamically compacted, a period of B-25 box structural collapse (i.e. a subsidence period) has been assumed to be from 100 to 150 years after burial and dynamic compaction.
- It is assumed that the closure cap over the Engineered Trench will consist of a high-density polyethylene (HDPE), flexible membrane liner (FML) over a geosynthetic clay liner (GCL) over a clayey sand foundation layer.
- A direct linear relationship is assumed between cost and the acreage of the closure cap.
- It is assumed that the Operating and Maintenance costs associated with FML/GCL closure caps can be determined from the 2 and 5 acre cap estimates as determined from a 1993 study (Bhutani, et al., 1993). Table A-21 presents the O&M costs, excluding subsidence repair costs, for a 2 and 5 acre FML/GCL closure cap. The subsidence repair costs were evaluated previously.

Table A-21. FML/GCL Closure Cap Yearly O&M Estimates (Excluding Cap Subsidence Repair Costs)

Closure Cap O&M Activities	1993 2-Acre FML/GCL Cover ($)	1993 5-Acre FML/GCL Cover ($)
Monthly Inspection	4,500	5,400
Annual Subsidence Survey	1,500	1,800
Vegetative Cover Maintenance	1,200	2,500
Total Closure Cap Yearly O&M Cost	7,200	9,700

Cumulative Operating and Maintenance Cost Calculations:

- The yearly O&M cost for a closure cap over an Engineered Trench containing B-25s, which have been processed through the WSF/SCF, has been calculated as follows:

  Closure Cap Acreage = 2.61 acres

  The cost has been escalated from 1993 to 2001 based upon a yearly 3% inflation rate (8 years at a F/P factor of 1.2668) (Grant, et al., 1976)

  Yearly O&M Cost $= 1.2668 \times (\$7,200 + ((\$9,700 - \$7,200) \times ((2.61 - 2) \div (5 - 2))))$

  $= \$9,765$

- The yearly O&M cost for a closure cap over an Engineered Trench containing B-25s, which have not been processed through the WSF/SCF has been calculated as follows:

  Closure Cap Acreage = 4.28 acres

  The cost has been escalated from 1993 to 2001 based upon a yearly 3% inflation rate (8 years at a F/P factor of 1.2668) (Grant, et al., 1976)

  Yearly O&M Cost $= 1.2668 \times (\$7,200 + ((\$9,700 - \$7,200) \times ((4.28 - 2) \div (5 - 2))))$

  $= \$11,528$

- Table A-22 provides the closure cap surface area, the yearly O&M cost, and the subsidence period associated with each case:

Table A-22. Closure Cap Parameters

Subsidence Treatment	Closure Cap Surface Area (acres)	Yearly O&M Cost ($)	Subsidence Period (years)
ISC	4.28	11,528	200 to 300
ISC and WSF/SCF	2.61	9,765	200 to 300
ISC and SDC	4.28	11,528	100 to 150
ISC and TDC	4.28	11,528	100 to150
ISC, WSF/SCF, and SDC	2.61	9,765	100 to 150
ISC, WSF/SCF, and TDC	2.61	9,765	100 to 150

- The relative cumulative O&M cost has been calculated in Table A-23 for each case:

Table A-23. Relative Cumulative O&M Cost

Subsidence Treatment	Relative Cumulative O&M Cost ($)
ISC	= $11,528/year × 300 years = 3,458,400
ISC and WSF/SCF	= $9,765/year × 300 years = 2,929,500
ISC and SDC	= $11,528/year × 150 years = 1,729,200
ISC and TDC	= $11,528/year × 150 years = 1,729,200
ISC, WSF/SCF, and SDC	= $9,765/year × 150 years = 1,464,750
ISC, WSF/SCF, and TDC	= $9,765/year × 150 years = 1,464,750

Table A-24. Cumulative Operating and Maintenance Cost Summary:

Subsidence Treatment	Relative Cumulative O&M Cost ($)
ISC	3,458,400
ISC and WSF/SCF	2,929,500
ISC and SDC	1,729,200
ISC and TDC	1,729,200
ISC, WSF/SCF, and SDC	1,464,750
ISC, WSF/SCF, and TDC	1,464,750

ISC = Interim Soil Cover
WSF/SCF = Waste Sort Facility / Super Compactor Facility
SDC = Standard Dynamic Compaction
TDC = Tertiary Dynamic Compaction

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A-11 Relative Subsidence Potential and Cost Summary

Table A-25 through Table A-37 summarize the subsistence potential and cost summary.

Table A-25. Relative Subsidence Potential Summary

Subsidence Treatment Method	Relative Subsidence Potential (ft)	Relative Subsidence Potential Reduction (%)
ISC	13.616	9.9
ISC and WSF/SCF	11.702	22.6
ISC and SDC	10.402	31.2
ISC and TDC	7.189	52.4
ISC, WSF/SCF, and SDC	9.151	39.5
ISC, WSF/SCF, and TDC	6.601	56.3

Table A-26. Relative Closure Cost Summary

Subsidence Treatment Method	Relative Engineered Trench Design and Construction Cost ($)	Relative Subsidence Treatment Cost ($)	Relative FML/GCL Closure Cap Cost ($)	Total Relative Closure Cost [1] ($)
ISC	3,096,000	10,794,720	2,396,082	16,286,802
ISC and WSF/SCF	1,800,000	38,785,728	1,470,722	42,056,450
ISC and SDC	3,096,000	12,696,018	2,396,082	18,188,100
ISC and TDC	3,096,000	14,378,776	2,396,082	19,870,858
ISC, WSF/SCF, and SDC	1,800,000	39,983,327	1,470,722	43,254,049
ISC, WSF/SCF, and TDC	1,800,000	40,962,386	1,470,722	44,233,108

[1] Total Closure Cost = Design and Construction Cost + Subsidence Treatment Cost + Closure Cap Cost

Table A-27. Closure Cost to Subsidence Potential Reduction Ratio

Subsidence Treatment Method	Total Relative Closure Cost ($)	Relative Subsidence Potential Reduction (%)	Closure Cost per Subsidence Potential Reduction [1] ($ / %)
ISC	16,286,802	9.9	1,642,457
ISC and WSF/SCF	42,056,450	22.6	1,860,905
ISC and SDC	18,188,100	31.2	582,952
ISC and TDC	19,870,858	52.4	379,215
ISC, WSF/SCF, and SDC	43,254,049	39.5	1,095,039
ISC, WSF/SCF, and TDC	44,233,108	56.3	785,668

[1] Closure Cost per Subsidence Potential Reduction = Total Closure Cost ÷ Subsidence Potential Reduction

Table A-28. Traditional Method Relative Long-Term Maintenance Cost Summary

Subsidence Treatment Method	Relative Cap Subsidence Repair Cost – Traditional Method ($)	Relative Cumulative O&M Cost ($)	Total Relative Long-term Maintenance Cost [1] ($)
ISC	151,667,880	3,458,400	155,126,280
ISC and WSF/SCF	75,211,500	2,929,500	78,141,000
ISC and SDC	115,981,320	1,729,200	117,710,520
ISC and TDC	80,294,760	1,729,200	82,023,960
ISC, WSF/SCF, and SDC	59,650,500	1,464,750	61,115,250
ISC, WSF/SCF, and TDC	41,496,000	1,464,750	42,960,750

[1] Total Relative Long-term Maintenance Cost = Cap Subsidence Repair Cost + Cumulative O&M Cost

Table A-29. Traditional Method Long-Term Maintenance Cost to Subsidence Potential Reduction Ratio

Subsidence Treatment Method	Total Relative Long-term Maintenance Cost ($)	Relative Subsidence Potential Reduction (%)	Long-term Maintenance Cost per Subsidence Potential Reduction [1] ($ / %)
ISC	155,126,280	9.9	15,669,321
ISC and WSF/SCF	78,141,000	22.6	3,457,566
ISC and SDC	117,710,520	31.2	3,772,773
ISC and TDC	82,023,960	52.4	1,565,343
ISC, WSF/SCF, and SDC	61,115,250	39.5	1,547,222
ISC, WSF/SCF, and TDC	42,960,750	56.3	763,068

[1] Long-term Maintenance Cost per Subsidence Potential Reduction = Total Long-term Maintenance Cost ÷ Subsidence Potential Reduction

Table A-30. Traditional Method Total Relative Cost Summary

Subsidence Treatment Method	Total Relative Closure Cost ($)	Total Relative Long-term Maintenance Cost ($)	Total Relative Cost [1] ($)
ISC	16,286,802	155,126,280	171,413,082
ISC and WSF/SCF	42,056,450	78,141,000	120,197,450
ISC and SDC	18,188,100	117,710,520	135,898,620
ISC and TDC	19,870,858	82,023,960	101,894,818
ISC, WSF/SCF, and SDC	43,254,049	61,115,250	104,369,299
ISC, WSF/SCF, and TDC	44,233,108	42,960,750	87,193,858

[1] Total Relative Cost = Total Closure Cost + Total Long-term Maintenance Cost

Table A-31. Traditional Method Total Cost To Subsidence Potential Reduction Ratio

Subsidence Treatment Method	Total Relative Cost ($)	Relative Subsidence Potential Reduction (%)	Total Cost per Subsidence Potential Reduction [1] ($ / %)
ISC	171,413,082	9.9	17,311,779
ISC and WSF/SCF	120,197,450	22.6	5,318,471
ISC and SDC	135,898,620	31.2	4,355,725
ISC and TDC	101,894,818	52.4	1,944,558
ISC, WSF/SCF, and SDC	104,369,299	39.5	2,642,261
ISC, WSF/SCF, and TDC	87,193,858	56.3	1,548,736

[1] Total Cost per Subsidence Potential Reduction = Total Cost ÷ Subsidence Potential Reduction

Table A-32. Traditional Method Total Relative Cost Summary

Subsidence Treatment Method	Total Relative Closure Cost ($)	Total Relative Long-term Maintenance Cost ($)	Total Relative Cost [1] ($)
ISC	16,286,802	155,126,280	171,413,082
ISC and WSF/SCF	42,056,450	78,141,000	120,197,450
ISC and SDC	18,188,100	117,710,520	135,898,620
ISC and TDC	19,870,858	82,023,960	101,894,818
ISC, WSF/SCF, and SDC	43,254,049	61,115,250	104,369,299
ISC, WSF/SCF, and TDC	44,233,108	42,960,750	87,193,858

[1] Total Relative Cost = Total Closure Cost + Total Long-term Maintenance Cost

Table A-33. Traditional Method Total Cost to Subsidence Potential Reduction Ratio

Subsidence Treatment Method	Total Relative Cost ($)	Relative Subsidence Potential Reduction (%)	Total Cost per Subsidence Potential Reduction [1] ($ / %)
ISC	171,413,082	9.9	17,311,779
ISC and WSF/SCF	120,197,450	22.6	5,318,471
ISC and SDC	135,898,620	31.2	4,355,725
ISC and TDC	101,894,818	52.4	1,944,558
ISC, WSF/SCF, and SDC	104,369,299	39.5	2,642,261
ISC, WSF/SCF, and TDC	87,193,858	56.3	1,548,736

[1] Total Cost per Subsidence Potential Reduction = Total Cost ÷ Subsidence Potential Reduction

Table A-34. Cap Replacement Method Relative Long-Term Maintenance Cost Summary

Subsidence Treatment Method	Relative Cap Subsidence Repair Cost ($)	Relative Cumulative O&M Cost ($)	Total Relative Long-term Maintenance Cost [1] ($)
ISC	49,838,506	3,458,400	53,296,906
ISC and WSF/SCF	26,178,851	2,929,500	29,108,351
ISC and SDC	18,929,048	1,729,200	20,658,248
ISC and TDC	12,938,843	1,729,200	14,668,043
ISC, WSF/SCF, and SDC	10,147,982	1,464,750	11,612,732
ISC, WSF/SCF, and TDC	7,353,610	1,464,750	8,818,360

[1] Total Long-term Maintenance Cost = Cap Subsidence Repair Cost + Cumulative O&M Cost

Table A-35. Cap Replacement Method Long-Term Maintenance Cost to Subsidence Potential Reduction Ratio

Subsidence Treatment Method	Total Relative Long-term Maintenance Cost ($)	Relative Subsidence Potential Reduction (%)	Long-term Maintenance Cost per Subsidence Potential Reduction [1] ($ / %)
ISC	53,296,906	9.9	5,383,526
ISC and WSF/SCF	29,108,351	22.6	1,287,980
ISC and SDC	20,658,248	31.2	662,123
ISC and TDC	14,668,043	52.4	279,924
ISC, WSF/SCF, and SDC	11,612,732	39.5	293,993
ISC, WSF/SCF, and TDC	8,818,360	56.3	156,632

[1] Long-term Maintenance Cost per Subsidence Potential Reduction =
Total Long-term O&M Cost ÷ Subsidence Potential Reduction

Table A-36. Cap Replacement Method, Total Relative Cost Summary

Subsidence Treatment Method	Total Relative Closure Cost ($)	Total Relative Long-term Maintenance Cost ($)	Total Relative Cost [1] ($)
ISC	16,286,802	53,296,906	69,583,708
ISC and WSF/SCF	42,056,450	29,108,351	71,164,801
ISC and SDC	18,188,100	20,658,248	38,846,348
ISC and TDC	19,870,858	14,668,043	34,538,901
ISC, WSF/SCF, and SDC	43,254,049	11,612,732	54,866,781
ISC, WSF/SCF, and TDC	44,233,108	8,818,360	53,051,468

[1] Total Cost = Total Closure Cost + Total Long-term Maintenance Cost

Table A-37. Cap Replacement Method, Total Relative Cost To Subsidence Potential Reduction Ratio

Subsidence Treatment Method	Total Relative Cost – Cap Replacement Method ($)	Relative Subsidence Potential Reduction (%)	Total Cost per Subsidence Potential Reduction–Cap Replacement Method [1] ($ / %)
ISC	69,583,708	9.9	7,028,657
ISC and WSF/SCF	71,164,801	22.6	3,148,885
ISC and SDC	38,846,348	31.2	1,245,075
ISC and TDC	34,538,901	52.4	659,139
ISC, WSF/SCF, and SDC	54,866,781	39.5	1,389,032
ISC, WSF/SCF, and TDC	53,051,468	56.3	942,300

[1] Total Cost per Subsidence Potential Reduction = Total Cost ÷ Subsidence Potential Reduction
ISC = Interim Soil Cover
WSF/SCF = Waste Sort Facility / Super Compactor Facility
SDC = Standard Dynamic Compaction
TDC = Tertiary Dynamic Compaction

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APPENDIX B

EMAILS

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B-1 Bunker, G. R., Internal SRS Email Dated 5/14/01 (2001a)

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Gary03 Bunker

To: Tom Butcher/WSRC/Srs@Srs
cc:
Subject: Super Compactor Facility Baseline Costs

05/14/01 08:38 AM

Attached below is the LLW baseline input information. The Super Compactor Facility costs are located under the "Waste Treatment" tab.

Please share this information with whomever in your organization needs it (Elmer Whilhite, etc.)

If you have any questions, please call me at 2-3295.

LLW Calculation Sheets.›

LLW Waste Treatment Facilities
Chart immediately below NOT to be used for data input purposes

				FY2001	FY2002	FY2003	FY2004	FY2005	FY2006	FY2007	FY2008	FY2009	FY2010	FY2011	FY2012	FY2013	FY2014
Materials	STP01 - MT		$K	133,500													
Subcontracts	STP02 - SC	RCS RADCON	$K	693,500													
Subcontracts	STP02 - SC	PALEX	$K	245,500													
RADCON	STP03 - WD	ESHQA_01	$K	915,500													
CMO Support	STP03 - WD	FECD_24	$K	209,900													
Engineering - EX	STP13 - EX		Hrs	4,100													
Operations - EX	STP14 - EX		Hrs	6,400													
Operations - NX	STP14 - NX		Hrs	38,500													
Training & Procedures - EX	STP17 - EX		Hrs	100													
		Total Cost	$K	4,215,475													

Waste Sort Facility
WBS 1.11.21.05.02.02.01

				FY2001	FY2002	FY2003	FY2004	FY2005	FY2006	FY2007
		Volume	m3	3,100	3,800	4,300	3,900	1,850	2,214	
Materials	SW11 - MT		$K	100,000	100,000	100,000	100,000	65,000	65,000	0
Subcontracts	SW12 - SC	RCS RADCON	$K	332,500	332,500	332,500	332,500	216,125	216,125	0
Subcontracts	SW12 - SC	PALEX	$K	156,667	156,667	156,667	156,667	101,833	101,833	0
Subcontracts	SW12 - SC	Facility Teardn	$K	0	0	0	0	0	0	150,000
RADCON	SW13 - WD	ESHQA_01	$K	477,750	477,750	477,750	477,750	310,538	310,538	0
CMO Support	SW13 - WD	FECD_24	$K	133,333	133,333	133,333	133,333	86,667	86,667	0
Engineering - EX	SW13 - EX		Hrs	2,067	2,067	2,067	2,067	1,343	1,343	1,550
Operations - EX	SW14 - EX		Hrs	6,267	6,267	6,267	6,267	4,073	4,073	0
Operations - NX	SW14 - NX		Hrs	22,333	22,333	22,333	22,333	14,517	14,517	0
Training & Procedures - EX	SW17 - EX		Hrs	67	67	67	67	43	43	0
		Total Cost	$K	1,409,557	2,609,567	2,996,567	2,800,567	1,686,218	1,786,218	845,752

Per Dutch Conrad during FY2000 System Plan update, WSF is approximately 2/3 of Waste Treatment Facility Costs.
Per T. V. Smith, RADCON costs are split 50/50 between WSF and SCF.
Includes facility teardown in FY2007 est $150K plus approximately 1 Engineering FTE.
FY2002-FY2004 budgets reduced to match FY2001 LRR per J. Blankenhorn 2/15/2001

Super Compactor Facility
WBS 1.11.21.05.02.02.01

				FY2001	FY2002	FY2003	FY2004	FY2005	FY2006	FY2007	FY2008	FY2009	FY2010	FY2011	FY2012	FY2013	FY2014
		Volume	m3	5,146	4,618	4,115	4,510	3,549	3,081	1,824	1,728	1,804	1,601	1,555	1,555	1,525	1,555
Materials	SW01 - MT		$K	50,000	50,000	50,000	50,000	37,500	37,500	17,500	17,500	17,500	17,500	15,000	15,000	15,000	15,000
Subcontracts	SW02 - SC	RCS RADCON	$K	332,500	332,500	332,500	332,500	193,875	193,875	116,375	116,375	116,375	116,375	99,750	99,750	99,750	99,750
Subcontracts	SW02 - SC	PALEX	$K	78,333	78,333	78,333	78,333	43,083	43,083	27,417	27,417	27,417	27,417	23,500	23,500	23,500	23,500
RADCON	SW03 - WD	ESHQA_01	$K	477,750	477,750	477,750	477,750	262,763	262,763	167,213	167,213	167,213	167,213	143,325	143,325	143,325	143,325
CMO Support	SW03 - WD	FECD_24	$K	66,667	66,667	66,667	66,667	36,667	36,667	23,333	23,333	23,333	23,333	20,000	20,000	20,000	20,000
Compactor Overhaul	SW04 - PC	FECD_31	$K	0	0	0	0	0	0	0	0	0	0	0	0	0	1,000,000
New Facility Structure	SW04 - PC	FECD_31	$K	0	0	0	0	0	0	0	0	1,000,000	1,000,000	0	0	0	0
Engineering - EX	SW13 - EX		Hrs	1,033	1,033	1,033	1,033	568	568	362	362	362	362	310	310	310	310
Operations - EX	SW14 - EX		Hrs	3,133	3,133	3,133	3,133	1,723	1,723	1,097	1,097	1,097	1,097	940	940	940	940
Operations - NX	SW14 - NX		Hrs	11,167	11,167	11,167	11,167	6,142	6,142	3,908	3,908	3,908	3,908	3,350	3,350	3,350	3,350
Training & Procedures - EX	SW17 - EX		Hrs	33	33	33	33	18	18	12	12	12	12	10	10	10	10
		Total Cost	$K	1,709,908	1,709,908	1,709,908	1,709,908	940,453	940,453	598,455	598,455	1,598,455	1,598,455	512,973	512,973	512,973	1,512,973

Per Dutch Conrad during FY2000 System Plan update, SCF is approximately 1/3 of Waste Treatment Facility Costs.
Per T. V. Smith, RADCON costs are split 50/50 between WSF and SCF.
Overhaul in FY2014 then every 10-15+ years thereafter based on volume.
Facility to move from current site to a TRU Pad (?) FY2009-FY2010.

LLW-6 Bulk Metals to Survey/Decon WBS 1.11.21.05.02.02.01		Volumes	m3	0	0	0	0	0	0	0	0	0	17	2	0	0	0
				FY2001	FY2002	FY2003	FY2004	FY2005	FY2006	FY2007	FY2008	FY2009	FY2010	FY2011	FY2012	FY2013	FY2014
Subcontracts	SW10 - SC		$K	0	0	0	0	0	0	0	0	0	14,700	500	0	0	0
HMTR Support	SW10 - WD	ATD_02	$K	0	0	0	0	0	0	0	0	0	2,550	100	0	0	0
RADCON Support	SW10 - WD	ESHQA_01	$K	0	0	0	0	0	0	0	0	0	1,275	50	0	0	0
Engineering - EX	SW13 - EX		hrs	0	0	0	0	0	0	0	0	0	34	1	0	0	0
Operations - EX	SW14 - EX		hrs	0	0	0	0	0	0	0	0	0	34	1	0	0	0
Operations - NX	SW14 - NX		hrs	0	0	0	0	0	0	0	0	0	34	1	0	0	0
		Total Cost	$K	0	0	0	0	0	0	0	0	0	[illegible]	900	0	0	0

System Plan has cost of $450/m3 but no details
Assume mainly subcontract with some SWD labor / WAD support
Subcontracts - $300/m3
Engineering - 4 hrs/m2
Operations EX - 4 hrs/m3
Operations NX - 3 hrs/m3
RADCON - $25/m3
HMTR - $50/m3

LLW-7 Contam Large Equip to Survey/Decon WBS 1.11.21.05.02.02.01		Volumes	m3	0	0	0	0	0	0	0	0	0	700	700	700	700	700
				FY2001	FY2002	FY2003	FY2004	FY2005	FY2006	FY2007	FY2008	FY2009	FY2010	FY2011	FY2012	FY2013	FY2014
Subcontracts	SW10 - SC		$K	0	0	0	0	0	0	0	0	0	210,000	210,000	210,000	210,000	210,000
HMTR Support	SW10 - WD	ATD_02	$K	0	0	0	0	0	0	0	0	0	35,000	35,000	35,000	35,000	35,000
RADCON Support	SW10 - WD	ESHQA_01	$K	0	0	0	0	0	0	0	0	0	17,500	17,500	17,500	17,500	17,500
Engineering - EX	SW13 - EX		Hrs	0	0	0	0	0	0	0	0	0	350	350	350	350	350
Operations - EX	SW14 - EX		Hrs	0	0	0	0	0	0	0	0	0	350	350	350	350	350
Operations - NX	SW14 - NX		Hrs	0	0	0	0	0	0	0	0	0	350	350	350	350	350
		Total Cost	$K	0	0	0	0	0	0	0	0	0	317,350	317,350	317,350	317,350	317,350

System Plan has cost of $452/m3 but no details
Assume mainly subcontract with some SWD labor / WAD support
Subcontracts - $300/m3
Engineering - .5 hrs/m3
Operations EX - .5 hrs/m3
Operations NX - .5 hrs/m3
RADCON - $25/m3
HMTR - $50/m3

LLW-8 Contam Large Equip to Size Reduce WBS 1.11.21.05.02.02.01		Volumes	m3	0	0	0	0	0	0	0	0	0	184	184	184	184	184
				FY2001	FY2002	FY2003	FY2004	FY2005	FY2006	FY2007	FY2008	FY2009	FY2010	FY2011	FY2012	FY2013	FY2014
Subcontracts	SW10 - SC		$K	0	0	0	0	0	0	0	0	0	368,000	368,000	368,000	368,000	368,000
HMTR Support	SW10 - WD	ATD_02	$K	0	0	0	0	0	0	0	0	0	27,600	27,600	27,600	27,600	27,600
RADCON Support	SW10 - WD	ESHQA_01	$K	0	0	0	0	0	0	0	0	0	13,800	13,800	13,800	13,800	13,800
Engineering - EX	SW13 - EX		Hrs	0	0	0	0	0	0	0	0	0	736	736	736	736	736
Operations - EX	SW14 - EX		Hrs	0	0	0	0	0	0	0	0	0	736	736	736	736	736
Operations - NX	SW14 - NX		Hrs	0	0	0	0	0	0	0	0	0	736	736	736	736	736
		Total Cost	$K	0	0	0	0	0	0	0	0	0	525,224	525,224	525,224	525,224	525,224

System Plan has cost of $2,850/m3 but no details
Assume mainly subcontract with some SWD labor / WAD support
Subcontracts - $2000/m3
Engineering - 4 hrs/m3
Operations EX - 4 hrs/m3
Operations NX - 4 hrs/m3
RADCON - $75/m3
HMTR - $150/m3

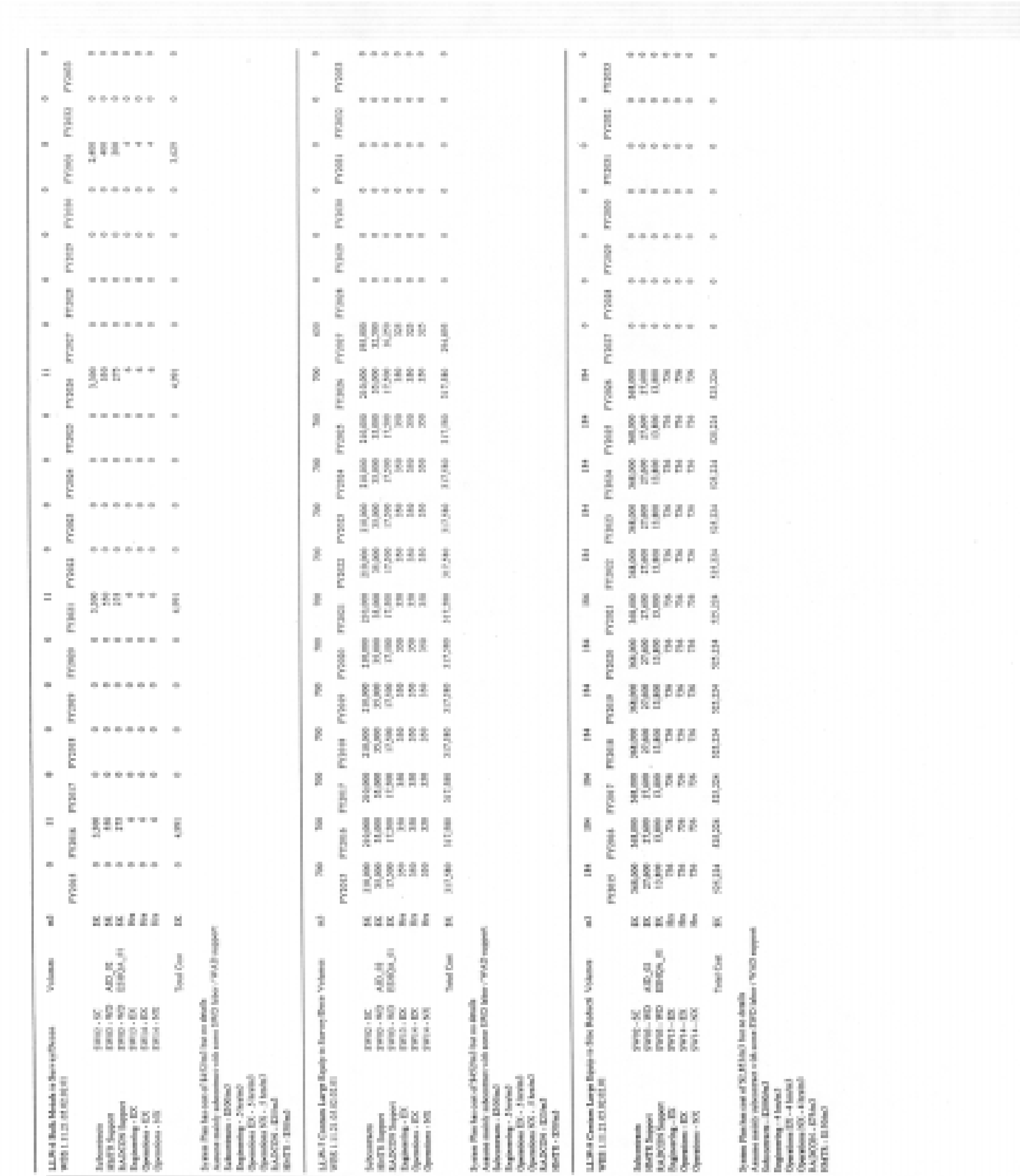
LLW Waste Treatment Facilities				FY2015	FY2016	FY2017	FY2018	FY2019	FY2020	FY2021	FY2022	FY2023	FY2024	FY2025	FY2026	FY2027	FY2028	FY2029	FY2030	FY2031	FY2032	FY2033
Close temporarily before WSF to be used for data input purposes																						
Materials	*SW01 - MT*		*$K*																			
Subcontracts	*SW02 - SC*	*KCS RADCON*	*$K*																			
Subcontracts	*SW02 - SC*	*FALEX*	*$K*																			
RADCON	*SW03 - WD*	*ESHQA_31*	*$K*																			
CMO Support	*SW03 - WD*	*FECD_24*	*$K*																			
Engineering - EX	*SW13 - EX*		*Hrs*																			
Operations - EX	*SW14 - EX*		*Hrs*																			
Operations - NX	*SW14 - NX*		*Hrs*																			
Training & Procedures - EX	*SW17 - EX*		*Hrs*																			
		Total Cost	*$K*																			

Waste Sort Facility		Volumes	m3
WBS 1.1I. 21.37.09.02.31			
Materials	SWX1 - MT		$K
Subcontracts	SWX2 - SC	KCS RADCON	$K
Subcontracts	SWX2 - SC	FALEX	$K
Subcontracts	SWX2 - SC	Facility Trends	$K
RADCON	SWX3 - WD	ESHQA_31	$K
CMO Support	SWX3 - WD	FECD_24	$K
Engineering - EX	SW13 - EX		Hrs
Operations - EX	SW14 - EX		Hrs
Operations - NX	SW14 - NX		Hrs
Training & Procedures - EX	SW17 - EX		Hrs
		Total Cost	$K

Per Dutch Consul during FY2000 System Plan update, WSF is approxi
Per T. V. Smith, RADCON costs are split 50/50 between WSF and SCF.
Includes facility markdown in FY2005 with $250K plus approximately 1
FY2002-FY2004 budgets reduced to match FY2001 LRE per J. Blum

Super Compactor Facility		Volumes	m3	1,555	1,273	1,353	1,370	1,370	1,278	1,303	1,375	1,355	1,285	1,332	1,277	1,277	1,277	1,277	1,277	624	624	624
WBS 1.1I. 21.35.02.52.31				FY2015	FY2016	FY2017	FY2018	FY2019	FY2020	FY2021	FY2022	FY2023	FY2024	FY2025	FY2026	FY2027	FY2028	FY2029	FY2030	FY2031	FY2032	FY2033
Materials	SWY1 - MT		$K	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	7,500	7,500	7,500
Subcontracts	SWY2 - SC	KCS RADCON	$K	99,750	99,750	99,750	99,750	99,750	99,750	99,750	99,750	99,750	99,750	99,750	99,750	99,750	99,750	99,750	99,750	49,875	49,875	49,875
Subcontracts	SWY2 - SC	FALEX	$K	23,500	23,500	23,500	23,500	23,500	23,500	23,500	23,500	23,500	23,500	23,500	23,500	23,500	23,500	23,500	23,500	11,750	11,750	11,750
RADCON	SWY3 - WD	ESHQA_31	$K	143,325	143,325	143,325	143,325	143,325	143,325	143,325	143,325	143,325	143,325	143,325	143,325	143,325	143,325	143,325	143,325	71,663	71,662	71,662
EMO Support	SWY3 - WD	FECD_24	$K	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	10,000	10,000	10,000
Compactor Overhaul	SWY4 - PC	FECD_21	$K	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,000,000	0	0	0	0
New Facility Structure	SWY4 - PC	FECD_21	$K	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Engineering - EX	SW13 - EX		Hrs	310	310	310	310	310	310	310	310	310	310	310	310	310	310	310	310	155	155	155
Operations - EX	SW14 - EX		Hrs	940	940	940	940	940	940	940	940	940	940	940	940	940	940	940	940	470	470	470
Operations - NX	SW14 - NX		Hrs	3,350	3,350	3,350	3,350	3,350	3,350	3,350	3,350	3,350	3,350	3,350	3,350	3,350	3,350	3,350	3,350	1,675	1,675	1,675
Training & Procedures - EX	SW17 - EX		Hrs	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	5	5	5
		Total Cost	$K	312,975	312,975	312,975	312,975	312,975	312,975	312,975	312,975	312,975	312,975	312,975	312,975	312,975	312,975	1,312,975	312,975	156,488	156,488	156,488

Per Dutch Consul during FY2000 System Plan update, SCF is approxim
Per T. V. Smith, RADCON costs are split 50/50 between WSF and SCF
Overhaul in FY2004 then every 10-15 years thereafter based on volum
Facility to move from current vault cell to a TRU Pad (?) FY2009-FY20



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B-2 Bunker, G. R., Internal SRS Email Dated 5/16/01 (2001b)

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Gary03 Bunker

To: Elmer Wilhite/WSRC/Srs@Srs
cc:
Subject: Information needed to complete Supercompaction cost study

05/16/01 01:47 PM

----- Forwarded by Gary03 Bunker/BSRI/Srs on 05/16/01 01:49 PM -----

Gary03 Bunker

To: Cliff Thomas/WSRC/Srs@Srs, Mark Sackash/BSRI/Srs@Srs, J Paveglio/BSRI/Srs@Srs
cc:
Subject: Information needed to complete Supercompaction cost study

05/16/01 12:08 PM

Cliff, I found a little time to come up with some quick answers to Wilhite's questions below. Please let me know if you need any additional information. - Gary B. 2-3295

----- Forwarded by Gary03 Bunker/BSRI/Srs on 05/16/01 07:31 AM -----

Elmer Wilhite

To: Cliff Thomas/WSRC/Srs@Srs
cc: Mark Phifer/WSRC/Srs@Srs, Ed Stevens/WSRC/Srs@Srs, Tom Butcher/WSRC/Srs@Srs, Jim Cook/WSRC/Srs@srs
Subject: Information needed to complete Supercompaction cost study

05/14/01 04:25 PM

Cliff:

I've gotten a number of questions from Mark Phifer that will need your input. They are:

Q1) For the supercompaction case approximately 289,440 55-gallon drums would be required to compact waste in the B-25s in the Supercompaction case. Will the cost of these drums be included in the Yearly Supercompaction Cost provided by SWD or should we list them separately? If we are to list them separately what is the cost per 55-gallon drum?

A1) SWD purchases 55 gallon drums from Palex on multiple purchase orders. These costs are included in the baseline for both the SCF and the WSF.

Q2) We need the yearly cost that SWD want us to include for operation of the Supercompaction facility and we need to know how many supercompacted B-25s are produced per year. Who will provide this information?

A2) These costs are included in the baseline information I provided Tom Butcher on Monday. These costs vary slightly year by year as the volumes change, though generally they stay in a fairly tight range. Note that these costs are direct only (no SOH/ESS) and they don't include any facility support / program management spread. If these various adders are required, please let me know. Included with these costs are the projected volume (m3) input per year to the SCF. I assume you will be able to convert these volumes into 55 gallon drum and B-25 equivalents.

Q3) Should we double check the $500 / B-25 box cost at the same time that we are getting other information from SWD?

A3) B-25s in stores are listed at $500 per box. Lee Josey, however, stated that the site purchases these items on P. O. C001854 for $489.11 per box. Add to this is the inspection cost which appears to be extremely variable. Given historical cost data provided by Josey and Tony Nasol, an average inspection cost per B-25 is $34 per box. Josey, however, stated that SWD purchases relatively few B-25s which was corroborated by Lee Fox, who stated that most of the B-25s used at the SCF are "used" having already been sent by the waste generators and processed through the WSF.

Q4) The dynamic compaction cost data that I have is based upon work performed in 1998 and the repair cost may be from even earlier cost data. Should the dates associated with the cost estimates be listed or should such estimates be escalated based upon some inflation rate? If escalation is to be performed what inflation rate should we use?

A4) The latest costs are in the baseline data I provided Tom Butcher on Monday. These costs should supercede anything from 1998. As noted under (A2), these costs do not include any SOH/ESS or facility support / program management spreads. Furthermore, they are unescalated in current dollars. I assume a flat 3% escalation would be adequate. Mark, any ideas on this particular point?

We'll need this information to finalize our study.

Elmer

B-3 Bunker, G. R., Internal SRS Email Dated 5/17/01 (2001c)

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APPENDIX B - EMAILS
SECTION B-3

WSRC-RP-2001-00613

Gary03 Bunker
05/17/01 04:21 PM

To: Mark Phifer/WSRC/Srs@Srs
cc: Bob Aylward/WSRC/Srs@Srs, Cliff Thomas/WSRC/Srs@Srs, Elmer Wilhite/WSRC/Srs@Srs, Jim Cook/WSRC/Srs@srs, Tom Butcher/WSRC/Srs@Srs, Welford03 Goldston/WSRC/Srs@Srs, Mark Sackash/BSRI/Srs@Srs, J Paveglio/BSRI/Srs@Srs
Subject: Re: Additional Information Needs from SWD

For what its worth, my input to items below follow each question:

Mark Phifer

Mark Phifer
05/16/01 12:00 PM

To: Elmer Wilhite/WSRC/Srs@Srs
cc: Bob Aylward/WSRC/Srs@Srs, Tom Butcher/WSRC/Srs@Srs, Jim Cook/WSRC/Srs@srs, Cliff Thomas/WSRC/Srs@Srs, Gary03 Bunker/BSRI/Srs@Srs, Welford03 Goldston/WSRC/Srs@Srs
Subject: Additional Information Needs from SWD

Elmer the following are questions that we still need to have answered by SWD. We need answers to all of these questions to make sure that we are providing as appropriate a cost comparison as possible.

Q1) Are we to use the combined cost of $4,319,475 per year for the Waste Sort Facility ($2,609,567 per year) and Super Compactor Facility ($1,709,908) provided by Gary Bunker for our Super Compaction Cost in our evaluation?

A1) I don't know the precise scope of this study so I can't help on this question.

Q2) How may Super Compacted B-25s are produced per year? We need this number to know how many years worth of Super Compaction Costs to include in our evaluation. That is, our evaluation is based upon 7,236 B-25s that have been Super Compacted and we need to convert that into a number of years.

A2) The LLW waste algorithm should contain the appropriate historic data in regards to volume (m3). I think you need to work with SWD Operations to derive the statistics on the various containers.

Q3) Does the $4,319,475 per year include the cost of the associated B-25 boxes or is that a separate cost? If it is a separate cost, what is the cost of each individual B-25 box? $500?

A3) The $4,319,475 is for SWD costs only. If waste generators ship their waste to us in B-25s, and we reuse them, those costs are not included.

Q4) Does the $4,319,475 per year include the cost of the associated 55-gallon drums or is that a separate cost? If it is a separate cost, what is the cost of each individual 55-gallon drum? This could be important, since for the Super Compaction case approximately 289,440 55-gallon drums would be required to compact waste in the B-25s.

A4) Both the SCF and the WSF budgets include substantial budgets for the purchase of 55-gallon drums, particularly those reconditioned drums from IFCO Industrial Container Systems in Charlotte, NC at a cost of roughly $13 per drum. In the estimate, these drum costs are included under the Palex subcontract. There is additional material budget in these estimates that could be used for additional drum purchases if needed.

Q5) The dynamic compaction cost data that I have is based upon work performed in 1998 and the repair cost may be from even earlier cost data. Should the dates associated with the cost estimates be listed or should such estimates be escalated based upon some inflation rate? If escalation is to be performed what inflation rate should we use?

A5) Note that the SWD costs I provided Tom Butcher do not include any SOH/ESS or facility support / program management spreads. Furthermore, they are unescalated in current dollars. Please be sure that the "dynamic compaction" cost data is similar in what it does and does not include. As far as escalation is concered for "dynamic compaction," I'd assume a flat 3% escalation rate would be adequate. Mark, any ideas on this particular point?

Q6) The dynamic compaction cost data and probably the repair cost data that I have is for the subcontractor costs only and do not include RadCon, Engineering, Design, Operation, QC/QV etc. support. Do we want to what to add say a 50% increase in these cost to make them more equivalent to the Super Compaction Costs provided by SWD? This is reasonable based upon our experience with the MWMF where the overall project cost was $35MM and the subcontractor cost was $17 to $19MM. For dynamic compaction alone I do not believe that we would have a 100% increase over the subcontractor costs.

A6) I'd be able to comment if I had a full understanding of what the "dynamic compaction" cost estimate includes.

B-4 Bunker, G. R., Internal SRS Email Dated 6/5/01 (2001d)

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Gary03 Bunker
06/05/01 01:01 PM

To: Mark Phifer/WSRC/Srs@Srs
cc: Bob Aylward/WSRC/Srs@Srs, Cliff Thomas/WSRC/Srs@Srs, Elmer Wilhite/WSRC/Srs@Srs, Jim Cook/WSRC/Srs@srs, Leonard Collard/WSRC/Srs@Srs, Leroy Williams/WSRC/Srs@Srs, Michael Serrato/WSRC/Srs@Srs, Tom Butcher/WSRC/Srs@Srs, Welford03 Goldston/WSRC/Srs@Srs
Subject: Re: Items for Review and Questions

1. Regarding the cost per B-25 issue, the problem is that the cost estimate is derived from volumes in the SWD Baseline which are far greater than the volumes in this study. In FY02 the study is assuming 793 B-25s and in FY03 799 B-25s. The SWD Baseline, on the other hand, assumes that these costs are supporting 4,974 m3 in FY02 and 5,524 m3 in FY03. If the SWD Baseline volumes are considered accurate, then the smaller volumes covered in this study should only be using a fraction of the baseline costs.

2. Regarding the Engineered Trench cost issue, each trench will be able to hold only 11,400 B-25s instead 12,000. This is because, per Shawn Reed, phases 1 and 3 of each trench contain a sump which reduces their total capacity from 4,000 B-25s to 3,700 B-25s. Phase 2 is still expected to contain 4,000 B-25s. In round numbers, a good capital cost estimate for each phase is $600K (direct). The direct operating cost for disposal, per the SWD Baseline, is $84/m3.

Mark Phifer

Mark Phifer
06/01/01 01:51 PM

To: Elmer Wilhite/WSRC/Srs@Srs, Cliff Thomas/WSRC/Srs@Srs
cc: Tom Butcher/WSRC/Srs@Srs, Bob Aylward/WSRC/Srs@Srs, Welford03 Goldston/WSRC/Srs@Srs, Gary03 Bunker/BSRI/Srs@Srs, Leroy Williams/WSRC/Srs@Srs, Leonard Collard/WSRC/Srs@Srs, Jim Cook/WSRC/Srs@srs, Michael Serrato/WSRC/Srs@Srs
Subject: Items for Review and Questions

Elmer and Cliff,

This e-mail replies to Cliff's question concerning the 60/40 split and Sonny's and Gary's question concerning the number of supercompacted B-25s produced per year. I will call Cliff to discuss his question concerning the long term maintenance costs. I also have several calculation files that need reviewing to determine if the numbers and assumptions are correct and reasonable. Additionally at the end of this e-mail I have additional questions that need to be answered. I can not proceed with completion of the subsidence potential calculations and the cost calculations until this information is reviewed and the questions answered. Thanks for your review and input.

The following are the results of the calculations and the associated supporting calculation files:

- The average density of uncompacted B-25s placed within an Engineered Trench containing only uncompacted B-25 has been calculated at 0.1807 grams / cubic centimeter. See the attached file for the basis of this number ("ET with only Uncompacted B-25s Calcs.doc").

ET with only Uncompacted B-25s

- The average density of B-25s placed within an Engineered Trench that have been processed through the WSF/SCF is 0.3816 grams / cubic centimeter. For every 21.5 supercompacted B-25 boxes at an average density of 0.7201 grams / cubic centimeter there are 40.2 uncompacted B-25 boxes at an average density of 0.2006 grams / cubic centimeter. See the attached file for the basis of this number ("ET with WSF-SCF B-25 Processing Calcs.doc"). This file also contains a WSF/SCF process flow diagram, which forms the basis for understanding the number and density of B-25 boxes associated with processing through the WSF/SCF. This should provide the answer to Cliff's 60/40 split question.

ET with WSF-SCF B-25 Processing

- 1.62 B-25 boxes in an Engineered Trench containing only uncompacted B-25s is equivalent on a mass basis to 1 box in an Engineered Trench containing B-25s which have been processed through the WSF/SCF. See the attached file for the basis of this number ("Trench B-25 Mass Equivalency.doc").

Trench B-25 Mass Equivalen

- A cost of $5,643 / supercompacted B-25 box has been calculated based upon the cost information provided by Gary Bunker and the number of supercompacted boxes produced per year provided by LeRoy Williams. See the attached file for the basis of this number ("Cost per Supercompacted B-25 Box.doc"). This provides the basis for the number of supercompacted boxes produced per year that we used in answer to Sonney's and Gary's question. If any of these numbers have been incorrectly used we need input from SWD to correct them.

Cost per Supercompacted B-25

The following is a question for Elmer:

Does the Table 4 B-25 box waste densities exclude the B-25 box itself from the density?

The following is a question for both Elmer and Cliff (SWD):

Of the 70.3% of the B-25s that pass the WSF screening criteria, is there a difference in density between the B-25s that can be compacted versus the 15% that pass the WSF screening criteria but still can not be compacted? Can we determine these densities from our Table 4 data, if there is a difference?

The following is a qustion for Cliff and SWD:

What is the cost of constructing and operating one Engineered Trench containing 12,000 B-25 boxes (150 foot by 650 foot trench)? This information is necessary since the cost will vary depending upon whether or not WSF/SCF is utilized.

Thanks,

Mark

B-5 Roddy, N. S., Internal SRS Email Dated 4/16/01 (2001a)

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Nathaniel Roddy
04/16/01 07:51 AM

To: Elmer Wilhite/WSRC/Srs@Srs
cc: Jim Cook/WSRC/Srs@Srs, Leonard Collard/WSRC/Srs@Srs, Don Sink/BSRI/Srs@Srs, William Knopf/WSRC/Srs@Srs, Jawahar Kukreja/BSRI/Srs@Srs, Kevin Tempel/WSRC/Srs@Srs
Subject: Re: More Questions

Elmer,

Please find answers in blue text below. Someone in Don Sink's organization should be able to provide you the answer to your question number 2.

Thanks!
N. S. Roddy

Elmer Wilhite

Elmer Wilhite

To: Nathaniel Roddy/WSRC/Srs@Srs
cc: Jim Cook/WSRC/Srs@srs, Leonard Collard/WSRC/Srs@Srs
Subject: More Questions

04/12/01 03:37 PM

Nat:

I've attached a sheet summarizing most of the data you've supplied (I've left out all the miscellaneous container types). From the waste densities, we can estimate the subsidence potential of the boxes. We need some more information, however. So, could you think about the following questions for us?

1. How many pucks go into a box of supercompacted waste? What's the weight of the empty drum that becomes a puck?

Response: Using the 749 SCF containers meeting the ET limits, there are:

Average =	40 compacted drums
Median =	39 compacted drums
Maximum =	68 compacted drums
Minimum =	24 compacted drums
St. dev. =	7.5 compacted drums

Weight of empty drum = Average 36 lbs +/- 20%, based on Container Approval

2. How could we estimate the fraction of waste that is compactible in the supercompactor?

Response: I have included a few folks from SWE/LLW on copy distribution. I am certain they have this information readily available.

Thanks again for all the help!

Elmer

New Package Data.do

B-6 Roddy, N. S., Internal SRS Email Dated 4/21/01 (2001b)

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Nathaniel Roddy
04/21/01 08:10 AM

To: Elmer Wilhite/WSRC/Srs@Srs
cc: Anthony Hayes/WSRC/Srs@Srs, Jim Cook/WSRC/Srs@Srs, Leonard Collard/WSRC/Srs@Srs
Subject: Re: Waste Container Information

Elmer:

Here is the attached file listing, by container type, all containers with waste meeting the WSF screening criteria:

ET - NOT COMPACTED - CONTAINERS MEETING WSF.xls

These are waste containers with not yet compacted waste. There were 5759 containers of not yet compacted waste. Out of this total, 4044 containers met the WSF screening criteria. This leaves 1715 or 29.7% of the containers that failed the screening.

Please refer to your e-mail message below for the responses to your other questions in blue text.

Thanks!
N. S. Roddy
Elmer Wilhite

Elmer Wilhite
04/16/01 04:00 PM

To: Nathaniel Roddy/WSRC/Srs@Srs
cc: Jim Cook/WSRC/Srs@srs, Leonard Collard/WSRC/Srs@Srs, Anthony Hayes/WSRC/Srs@Srs
Subject: Waste Container Information

Nat:

As usual, I've found a few more questions to ask. I'm certainly glad you're a patient guy!

OK, here goes:

1. Are we still using the 253-H compactor?

Response: No. I believe the 253-H compactor was shut down around the beginning of CY 1996.

2. When you had sent the new data to me last week, you had included 4 spreadsheets. Two of them contained all the various containers (one had container specifics and one had waste cut information), one of them had the 253-H boxes and one had the supercompactor boxes. However, there's some difference in the number of containers from 253-H and the SCF. The container specifics spreadsheet has data on 222 boxes from 253-H while the Spreadsheet with only 253-H boxes has only 183. The container specifics spreadsheet has data on 632 SuperCompactor boxes (all but one of which has a container number starting with SC), 57 B-25 Yellow-Light boxes with container numbers starting with SC, and 81 Yellow 575# boxes with container numbers starting with SC (this totals 769 boxes whose numbers start with SC) while the spreadsheet with only SCF boxes has 749.

Response:

253-H: After the 253-H compactor was shut down, a few generators used the container type code number 9 (i.e. purple B-25) container for normal waste and sent this waste directly to the EAV. I did a query to check this and found this to be accurate. Therefore, the total of 183 from 253-H is correct.

SCF container: When I ran my query, I only searched for Supercompactor boxes that contained the Reconditioned 55-gallon drum. I forgot that some other 55-gallon drums had been compacted at SCF. I performed a query to check on this. Therefore, the 769 total is the correct number. Sorry!!

3. I spoke with Tony Hayes about which boxes go to the supercompactor versus which do not. Tony indicated that there are 3 screening criteria for boxes going to the sort facility (<1Ci tritium, <2,000 pounds of waste, <4.5E-3 Pu-239 equivalent). Could you sort through the boxes in the container specifics list and tell us the ones that could go to the sort facility? That way, we'll have a sense of the fraction of boxes that could be supercompacted. Tony indicated that, of the boxes that go to the sorting facility, about 15% are rejected as not being suitable for supercompaction.

Response: Refer to my response in the cover message.

Thanks!

Elmer

B-7 Thomas, L. C., Internal SRS Email Dated 6/4/01 (2001)

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Cliff Thomas
06/04/01 08:33 AM

To: Mark Phifer/WSRC/Srs@Srs
cc: Elmer Wilhite/WSRC/Srs@Srs, Jim Cook/WSRC/Srs@Srs, Welford03 Goldston/WSRC/Srs@Srs
Subject: Re: Items for Review and Questions

Mark,
Looks good. The only comment is in the first case you assign a single density to the 60% compactible fraction but in the compacted case you breakout the 15% WSF reject and assign a different density. For consistency, I suggest you use the same methodology for both cases. Additionally, the reject boxes from WSF should be considered to weight 1600-1700 lbs. The main reason for the rejects is that the boxes contain uncompactible metal that while below the WSF criteria of 2000lbs, little benefit could be gained by processing. This would be difficult to find in WITS however since the rejected boxes are not designated differently. Searching the path of every box would be needed to identify these rejects.

I believe I've answered all of your questions. If you have anymore pls call at 76317 or page at 11057.
thanks
cliff

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B-8 Wilhite, E. L., Internal SRS Email Dated 5/11/01 (2001a)

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Elmer Wilhite
05/11/01 12:12 PM

To: Mark Phifer/WSRC/Srs@Srs, Ed Stevens/WSRC/Srs@Srs, Cliff Thomas/WSRC/Srs@Srs, Shawn Reed/WSRC/Srs@Srs, Welford03 Goldston/WSRC/Srs@Srs, Tom Butcher/WSRC/Srs@Srs, Jim Cook/WSRC/Srs@srs
cc:
Subject: Revised LLW Container Data

As we discussed in our meeting on Tuesday, I've revised the density data on LLW containers to split out the B-25s not meeting the WSF screening criteria from those meeting the criteria. The containers not meeting the screening criteria are a little bit more dense than those meeting the criteria (0.2124 g/cm^3 versus 0.1673 g/cm^3), but the difference is small and will not change the projections Mark showed.

Elmer

Not Meet WSF Package Da

Low-Level Waste Containers for Trench Disposal

The following table presents a breakdown of the waste container information provided by Nat Roddy. For each type of container, the total number of containers and statistics on the density of the waste in the containers are presented. For SRS B-25 containers, those meeting the Waste Sort Facility (WSF) screening criteria are listed separately from those not passing the criteria.

Nat also provided an analysis of containers that meet the WSF screening criteria; on the average, 29.7% of the containers failed screening. Tony Hayes indicated that, of the boxes sent to the Waste Sort Facility, about 15% were rejected because the contents were unacceptable for compaction.

Nat also supplied the following information regarding the number of supercompacted drums that go into a B-25 containing supercompacted waste:

Average =	40 compacted drums	
	Median =	39 compacted drums
	Maximum =	68 compacted drums
	Minimum =	24 compacted drums
	St. dev. =	7.5 compacted drums

Weight of empty drum = Average 36 lbs +/- 20%, based on Container Approval

I propose we make the following assumptions to expedite estimating subsidence potential:

1. Consider only the SRS B-25 boxes. The non-SRS boxes and miscellaneous containers represent only about 14% of the total number of containers. The SRS B-12 boxes represent about 8% of the SRS boxes.
2. We also shouldn't consider the 183 boxes that were compacted in the 253-H compactor (i.e., B-25P (Purple Compactor B-25) compacted). This compactor is no longer operational.
3. We use the average density of the boxes versus the soil bulk density of 1.5 g/cm^3 to estimate subsidence potential.
4. The Engineered Trench will contain 12,000 B-25 boxes, stacked 4 high.
5. The supercompactor will be able to compact 60% of the boxes.
6. B-25 boxes are 1.83 meters long, 1.17 meters wide, and 1.19 meters high.

Two simple cases can then be constructed. One in which all of the containers in the Engineered Trench are uncompacted B-25s and the other in which 60% of the boxes contains super compacted waste. The subsidence potential for these two cases is:

1. The composite average uncompacted box density is 0.1747 g/cm^3 (i.e., combining the containers meeting WSF screening criteria and those not meting the criteria). Using the dimensions of the box, the box volume is 2.55x10^6 cm^3. Therefore, the average box contains 4.45x10^5 grams of waste. If the waste were to be compacted to a density of 1.5 g/cm^3, the resulting height of the waste (i.e., assuming the length and width remain the same) would be 14 cm (i.e., 4.45x10^5 grams divided by 1.5 g/cm^3 equals 2.97x10^5 cm^3; 2.97x10^5 cm^3 divided by 2.14x10^4 cm^2 (183 cm * 117 cm) gives the new height of 13.87 cm. Therefore, the subsidence potential for each layer of boxes is 105 cm and the total subsidence potential for a 4-high stack of boxes is 420 cm.
2. The average density of the supercompacted boxes is 0.7201 g/cm^3. Sixty percent of the boxes will be compacted. Therefore, the overall average density of the boxes in this case is 0.5020 g/cm^3 (0.6*0.7201 + 0.4*0.1748). Using the same logic as above, the subsidence potential for each row of boxes is 79 cm and that for the 4-high stack is 317 cm.

Therefore, supercompaction would reduce overall subsidence by 103 cm (i.e., 25%). Of course, supercompaction would also result in the engineered trench containing almost twice the number of uncompacted B-25 equivalents. I arrived at this by taking the average density of the supercompacted boxes times the dimensions of a B-25 to get the average weight of the contents as 1.84x10^6 grams. Then, using Nat's information above (i.e., each supercompacted box contains, on average, 40 pucks and each empty drum that is turned into a puck weighs 36 pounds), the amount of waste in the supercompacted box is 1.18x10^6 grams. Using the average density of uncompacted boxes of 0.1748 g/cm^3, and the box dimensions, each uncompacted box contains 4.45x10^5 grams of waste. Therefore, each supercompacted box contains waste equivalent to about 2.65 non-compacted boxes.

Container Description	Number of Boxes	Average Density, g/cc	Standard deviation	Minimum Density	Maximum Density	Median Density
SRS Boxes						
Meeting WSF Screening Criteria						
B-25 (YELLOW)-LIGHT	818	1.853E-01	1.650E-01	1.779E-02	1.119E+00	1.387E-01
B-25 (6,800# CAP) 6728	23	1.281E-01	5.011E-02	5.623E-02	2.354E-01	1.103E-01
B-25 (YELLOW) 5758	1042	1.965E-01	1.749E-01	3.024E-03	1.183E+00	1.424E-01
B-25 (YELLOW) 6258	1777	1.427E-01	6.269E-02	1.832E-02	3.549E-01	1.291E-01
B-25 OVERPACK - UNRESTRICTED	5	1.920E-01	3.388E-02	1.376E-01	2.411E-01	1.865E-01
B-25(YELLOW) 440 LBS	87	1.734E-01	6.499E-02	6.589E-02	3.416E-01	1.694E-01
SuperCompactor B-25 (5758) not compacted	1	1.658E-01	NA			
B-25P (Purple Compactor B-25) not compacted	12	9.391E-02	5.204E-02	2.653E-02	1.713E-01	8.681E-02
Total SRS uncompacted B-25s meeting WSF Screening Criteria	3767	1.673E-01	1.291E-01	3.824E-03	1.183E+00	1.357E-01
Not Meeting WSF Screening Criteria						
B-25 (YELLOW)-LIGHT	136	1.865E-01	1.475E-01	3.275E-02	6.790E-01	1.248E-01
B-25 (YELLOW) 5758	244	2.289E-01	1.908E-01	1.512E-02	8.485E-01	1.424E-01
B-25 (YELLOW) 6258	288	2.088E-01	1.695E-01	4.145E-02	8.627E-01	1.351E-01
B-25 OVERPACK - UNRESTRICTED	10	1.774E-01	4.375E-02	1.668E-01	2.545E-01	1.775E-01
B-25(YELLOW) 440 LBS	18	3.283E-01	1.744E-01	4.678E-02	5.850E-01	3.779E-01
B-25P (Purple Compactor B-25) not compacted	27	1.962E-01	9.140E-02	3.842E-02	3.332E-01	2.209E-01
Total SRS uncompacted B-25s not meeting WSF Screening Criteria	743	2.124E-01	1.707E-01	1.512E-02	8.627E-01	1.359E-01
SRS B-25 Boxes containing supercompacted waste	779	7.201E-01	9.854E-02	4.468E-01	1.341E+00	7.088E-01
B-25P (PURPLE COMPACTOR B-25) compacted	183	4.371E-01	8.179E-02	2.448E-01	7.208E-01	4.498E-01
B-12	434	4.765E-01	3.288E-01	1.187E-02	1.728E+00	4.138E-01
Non SRS Boxes						
BETTIS 12,500 CAPACITY B-25	128	1.026E+00	2.399E-01	1.116E-01	1.326E+00	1.085E+00
B-25(BETTIS)	284	4.298E-01	2.163E-01	3.735E-02	1.036E+00	3.949E-01
B-25, KAPL, Sing Tight, Unres.	211	4.050E-01	1.863E-01	1.270E-01	9.360E-01	3.691E-01
B-25 TYPE A (KNOLL-KAPL)	10	2.972E-01	1.618E-01	1.387E-01	5.657E-01	2.239E-01
B-25 PINELLAS	1	3.424E-02	NA	NA	NA	NA
B-12(BETTIS)	17	1.278E+00	3.222E-01	1.506E-01	1.669E+00	1.298E+00
B-12, KAPL, Sing Tight, Unrest	66	8.4541E-01	4.681E-01	2.470E-01	2.694E+00	7.899E-01
B-12 STRONG TIGHT (KNOLL)	3	1.368E+00	1.394E-01	1.227E+00	1.553E+00	1.317E+00
B-12 Type A (Knolls)	1	1.705E-01	NA	NA	NA	NA
Total non-SRS boxes	723					
Miscellaneous Containers						
55-Gal Drum (A,7A)	12	NA	NA	NA	NA	NA
Box for Jumper P-PJ-H-7878	1	NA	NA	NA	NA	NA
Empty 30-Gallon SS Drum	2	NA	NA	NA	NA	NA
MMSS Container for PVV	3	NA	NA	NA	NA	NA
B-1000 AGNS	2	NA	NA	NA	NA	NA
55 Gal Drum (UN1A2)	41	NA	NA	NA	NA	NA
55 Gal Drum (17H Battis)	9	NA	NA	NA	NA	NA
Bettis DOT 7A Type A	7	NA	NA	NA	NA	NA
KAPL-Windsor (B-82)	49	NA	NA	NA	NA	NA
KAPL-Windsor (B-87)	2	NA	NA	NA	NA	NA
KAPL-Knolls 55-gal drum	9	NA	NA	NA	NA	NA
KAPL-Kesselring 01-2800	25	NA	NA	NA	NA	NA
BAPL-Mixed Fission Products	4	NA	NA	NA	NA	NA
BAPL-Unirradiated Alpha	1	NA	NA	NA	NA	NA
KWD-Low Specific Activity	1	NA	NA	NA	NA	NA
SEG OP45(Retired Do Not Use)	34	NA	NA	NA	NA	NA
SRTC One-Time Shielded Cell	1	NA	NA	NA	NA	NA
SEG OP45	7	NA	NA	NA	NA	NA
KAPL-Windsor Steam Gen Un-Res	5	NA	NA	NA	NA	NA
SRTC Box – 16,000 LB. Capacity	1	NA	NA	NA	NA	NA
SRTC Box – 2000 LB. Capacity	1	NA	NA	NA	NA	NA
55-Gallon Drum, Carolina Metal	4	NA	NA	NA	NA	NA
85-Gallon, Stain. Steel Drum	15	NA	NA	NA	NA	NA
85-Gal Carbon Steel Drum, SW	3	NA	NA	NA	NA	NA
Empty Bung Hole 55-Gallon Drum	1	NA	NA	NA	NA	NA
Total Miscellaneous	240					
Total Number of Containers	6869					

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B-9 Wilhite, E. L., Internal SRS Email Dated 6/4/01 and issued at 7:29 am (2001b)

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Elmer Wilhite

To: Nathaniel Roddy/WSRC/Srs@Srs
cc: Mark Phifer/WSRC/Srs@Srs
Subject: Another Package Question

06/04/01 07:29 AM

Nat:

In the various spreadsheets that you had sent me, there's one that lists containers that pass the WSF screening criteria. From Tony Hayes, I learned that, of the boxes passing WSF screening criteria, about 15% are rejected from being supercompacted. Do we have a way of identifying those boxes that were rejected so that we can see if there's a density difference?

Thanks,

Elmer

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B-10 Wilhite, E. L., Internal SRS Email Dated 6/4/01 and issued at 9:59 am (2001c)

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Elmer Wilhite
To: Mark Phifer/WSRC/Srs@Srs
cc: Cliff Thomas/WSRC/Srs@Srs, Jim Cook/WSRC/Srs@srs, Tom Butcher/WSRC/Srs@Srs, Welford03 Goldston/WSRC/Srs@Srs
Subject: Re: Items for Review and Questions

06/04/01 09:59 AM

Mark:

I suggest that we assume the boxes rejected from WSF weigh 1,650 pounds which is equivalent to 748.43 kg. I used the container specifics spreadsheet that Nat had provided to determine the average weight of SRS B-25 boxes as 262.52 kg. Thus, the average box rejected by WSF would contain 485.91kg of waste.

Elmer
----- Forwarded by Elmer Wilhite/WSRC/Srs on 06/04/01 09:57 AM -----

Cliff Thomas
06/04/01 08:33 AM
To: Mark Phifer/WSRC/Srs@Srs
cc: Elmer Wilhite/WSRC/Srs@Srs, Jim Cook/WSRC/Srs@Srs, Welford03 Goldston/WSRC/Srs@Srs
Subject: Re: Items for Review and Questions

Mark,
Looks good. The only comment is in the first case you assign a single density to the 60% compactible fraction but in the compacted case you breakout the 15% WSF reject and assign a different density. For consistency, I suggest you use the same methodology for both cases. Additionally, the reject boxes from WSF should be considered to weight 1600-1700 lbs. The main reason for the rejects is that the boxes contain uncompactible metal that while below the WSF criteria of 2000lbs, little benefit could be gained by processing. This would be difficult to find in WITS however since the rejected boxes are not designated differently. Searching the path of every box would be needed to identify these rejects.

I believe I've answered all of your questions. If you have anymore pls call at 76317 or page at 11057.
thanks
cliff

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B-11 Wilhite, E. L., Internal SRS Email Dated 6/6/01 (2001d)

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Elmer Wilhite

To: Mark Phifer/WSRC/Srs@Srs
cc: Cliff Thomas/WSRC/Srs@Srs, Gary03 Bunker/BSRI/Srs@Srs
Subject: Capacity of Engineered Trench

06/06/01 02:39 PM

Mark:

I checked with Cliff Thomas regarding the capacity of the Engineered Trench. We have been assuming 12,000 B-25s, based on the equivalency between the LAW vault and the ET but Gary Bunker indicated the true capacity was 11,400 boxes. Cliff indicated that, for this study, the 12,000 box capacity is close enough.

Elmer

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B-12 Wilhite, E. L., Internal SRS Email Dated 6/14/01 (2001e)

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Elmer Wilhite
06/14/01 08:04 AM

To: Nathaniel Roddy/WSRC/Srs@Srs
cc: Mark Phifer/WSRC/Srs@Srs, Cliff Thomas/WSRC/Srs@Srs
Subject: Re: Re[2]: DIRECT SHIPMENTS TO SCF

Nat:

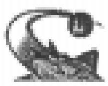
Thanks very much for getting this for us! The earlier sheets you had sent totalled 779 boxes from SCF. I forwarded you an email that you had sent me some time ago showing the 779 boxes of SCF waste.

Using the average number of compacted drums per box (40), the 779 boxes of compacted waste would contain 29,960 drums. Therefore, the 6095 drums that did not go through WSF are about 20% of the total.

Thanks again,

Elmer

Nathaniel Roddy



Nathaniel Roddy
06/14/01 07:38 AM

To: Elmer Wilhite/WSRC/Srs@Srs
cc:
Subject: Re: Re[2]: DIRECT SHIPMENTS TO SCF

Elmer,

I went back to all of my output files concerning the SCF containers. There were 749 containers from the SCF that met the trench criteria. I could not find anything in my files about an additional 30 containers. If I am missing something, please let me know.

Out of the 749, there are a total of 6095 compacted drums that were received from outside of the WSF.

I hope this helps!

If you have any questions, please let me know.

Thanks!
N. S. Roddy

Elmer Wilhite

Elmer Wilhite
06/12/01 04:04 PM

To: Nathaniel Roddy/WSRC/Srs@Srs
cc:
Subject: Re: Re[2]: DIRECT SHIPMENTS TO SCF

Nat:

Thanks for makin sure!

Yes. All we need is the number of compacted drums contained in the 779 B-25s that were sent directly to the compactor rather than through WSF. I do not need any other information on those drums.

Elmer
Nathaniel Roddy

Nathaniel Roddy
06/12/01 03:25 PM

To: Elmer Wilhite/WSRC/Srs@Srs
cc:
Subject: Re: Re[2]: DIRECT SHIPMENTS TO SCF

Elmer,

Just so I understand, your request is only for the number of compacted drums based on their origination that are contained within the 779 B-25s. If I am not correct, please let me know. Do you need any additional information about these drums?

Thanks!
N. S. Roddy

Elmer Wilhite

Elmer Wilhite

To: Cliff Thomas/WSRC/Srs@Srs
cc: Mark Phifer/WSRC/Srs@Srs, Tom Butcher/WSRC/Srs@Srs, Nathaniel Roddy/WSRC/Srs@Srs
Subject: Re: Re[2]: DIRECT SHIPMENTS TO SCF

06/12/01 07:18 AM

Cliff:

I was on the verge of calling you to say that I agreed with your idea that the drums sent by generators to the compactor (bypassing WSF) was implicitly included in the data set that we had analyzed. My rationale was that the data set spanned several years of E-Area operations and the direct drums was a recent innovation.

However, Tony's information indicates that the direct drum business has been going on for almost as long as the compactor has been operating and about 20% of drums compacted come directly from generators. Therefore, I believe we need Nat to generate for us the distribution of the compacted drums contained in the 779 B-25s containing compacted waste between those sent directly to SCF and those going through WSF.

I believe this will result in only a minor adjustment to our figures, but it will be accurate.

Elmer

----- Forwarded by Elmer Wilhite/WSRC/Srs on 06/12/01 07:13 AM -----

Anthony Hayes
06/11/01 03:52 PM

To: Elmer Wilhite/WSRC/Srs@Srs
cc:
Subject: Re: Re[2]: DIRECT SHIPMENTS TO SCF

The SCF began hot operations in June 1999 and has compacted 38,495 drums to date.

Elmer Wilhite

Elmer Wilhite
06/11/01 03:25 PM

To: Anthony Hayes/WSRC/Srs@Srs
cc:
Subject: Re[2]: DIRECT SHIPMENTS TO SCF

Tony:

When did the compactor first begin operations?

Elmer
Anthony Hayes

Anthony Hayes

To: Elmer Wilhite/WSRC/Srs@Srs
cc:
Subject: DIRECT SHIPMENTS TO SCF

06/11/01 02:17 PM

Elmer,

The compactor received its first shipment directly from generators on10/19/99. To date, the compactor has received 7,997 such drums. This data was obtained from a WITS query. Hope it helps.

Tony

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B-13 Williams, L., Internal SRS Email Dated 5/17/01 (2001a)

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Leroy Williams

To: Mark Phifer/WSRC/Srs@Srs
cc: Cliff Thomas/WSRC/Srs@Srs, Brent Daugherty/BSRI/Srs@Srs
Subject: B-25 Forecast From WSF and SCF

05/17/01 10:19 AM

Mark:

Cliff Thomas requested I provide you the attached forecast showing B-25 waste containers generated by the Super Compaction Facility (SCF) and Waste Sort Facility (WSF) through FY70.

Leroy
7-6378/13378

No B-25s From SCF&W

	A	B	C	D	E	F	G	H
1	Volumes in m3	Map Identifier	End FY97	FY98	FY99	FY00	FY01	FY02
2543	Est. No. of B-25s from Super Compaction Facility and Waste Sort/Segregation							
2544								
2545	Onsite Compactable to LAWV/Engineered Trench				N/A	N/A	772.95	643.15
2546								
2547	Low Activity Bulk Waste from Sort/Segregate to LAWV/Engineered Trench				N/A	N/A	150	150
2548								
2549	Total by FY						922	793

	A	B	I	J	K	L	M	N
1	Volumes in m3	Map Identifier	FY03	FY04	FY05	FY06	FY07	FY08
2543	Est. No. of B-25s from Super Compaction Facility and Waste Sort/Segregation							
2544								
2545	Onsite Compactable to LAWV/Engineered Trench		648.86	460.37	361.17	278.74	223.47	213.02
2546								
2547	Low Activity Bulk Waste from Sort/Segregate to LAWV/Engineered Trench		150	90	48	44	35	38
2548								
2549	Total by FY		799	548	409	323	263	251

	A	B	O	P	Q	R	S	T
1	Volumes in m3	Map Identifier	FY09	FY10	FY11-15	FY16-20	FY21-25	FY26-30
2543	Est. No. of B-25s from Super Compaction Facility and Waste Sort/Segregation							
2544								
2545	Onsite Compactable to LAWV/Engineered Trench		196.50	196.18	952.52	830.20	830.21	792.18
2546								
2547	Low Activity Bulk Waste from Sort/Segregate to LAWV/Engineered Trench		33	34	180	134	132	140
2548								
2549	Total by FY		230	230	1132	964	963	932

	A	B	U	V	W	X	Y	Z
1	Volumes in m3	Map Identifier	FY31-35	FY36-40	FY41-45	FY46-50	FY51-55	FY56-60
2543	Est. No. of B-25s from Super Compaction Facility and Waste Sort/Segregation							
2544								
2545	Onsite Compactable to LAWV/Engineered Trench		363.64	354.67	354.67	326.62	326.62	326.62
2546								
2547	Low Activity Bulk Waste from Sort/Segregate to LAWV/Engineered Trench		53	52	52	50	50	50
2548								
2549	Total by FY		416	407	407	376	376	376

	A	B	AA	AB	AC
1	Volumes in m3	Map Identifier	FY61-65	FY66-N	
2543	Est. No. of B-25s from Super Compaction Facility and Waste Sort/Segregation				TOTAL
2544					
2545	Onsite Compactable to LAWV/Engineered Trench		326.62	326.62	10012
2546					
2547	Low Activity Bulk Waste from Sort/Segregate to LAWV/Engineered Trench		50	50	1816
2548					
2549	Total by FY		376	376	11828

B-14 Williams, L., Internal SRS Email Dated 6/11/01 (2001b)

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Leroy Williams

06/11/01 01:48 PM

To: Mark Phifer/WSRC/Srs@Srs
cc: Brent Daugherty/BSRI/Srs@Srs, Cliff Thomas/WSRC/Srs
Subject: No. of B-25s from WSF

Mark:

The data that I sent on 5/17/01 is still good. Please use the line titled, "Onsite Compactable to LAWV/Engineering Trench." The data include only compacted drums in B-25s for disposal in the EAV and Trenches.

Leroy Williams

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